

The AMSAT[®] Journal

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Volume 23, No. 3

May/June 2000

CONTENTS

Amateur Radio Mobile/Handheld Satellite Communications.....1

By Bob Bruninga, WB4APR

Apogee View.....3

By Robin Haighton, VE3FRH

RS-13 and the DX Anomaly: Part 2.....10

By John Branegan, GM4IHJ

Yet Another Exciter for 23cm Work: Embedded Microcontrollers.....13

By Allan Copland, GM1SXX

Satellite Orbital Elements.....15

By Ray Hoad, WA5QGD

Observations from Norway.....16

By John Hackett, LA2QAA

Wideband & Low-Noise Microwave VCO.....18

By Matjav Vidmar, S53MV

AMSAT Journal Telemetry.....26

AMSAT VHF/UHF & HF Nets.....31

By Andy Reynolds, WD9IYT



Figure 1. W4HFZ's Mobile ASTARS Installation.

Amateur Radio Mobile/Handheld Satellite Communications

Bob Bruninga, WB4APR (wb4apr@amsat.org)

Although the outlook for commercialization of handheld and mobile satellite phones has been tarnished due to the high cost and small market, (IRIDIUM) there is nothing but good news for radio amateurs interested in this mode of communications. In just the last year we have seen the following hints at the true future of amateur mobile and handheld satellite communications:

[continued on page 4]

AMSAT-NA

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Satellite Tracking

with your PC and the Kansas City Tracker & Tuner



The **Kansas City Tracker** is a hardware and software package that connects between your rotor controller and an IBM XT, AT, or clone. It controls your antenna array, letting your PC track any satellite or orbital body. The **Kansas City Tracker** hardware consists of a half-size interface card that plugs into your PC. It can be connected directly to Kenpro 5400A/5600A or Yaesu G5400B/G5600B rotor controllers. It can be connected to other rotor assemblies using our Rotor Interface Option.

The **Kansas City Tuner** Option provides automatic doppler-shift compensation for digital satellite work. The **Tuner** is compatible with most rigs including Yaesu, Kenwood, and ICOM. It controls your radio thru the radio's serial computer port (if present) or through the radio's up/down mic-click interface. The **Kansas City Tuner** Option is perfect for low-orbit digital satellites like the NOAA and Microstat satellites.

The **Kansas City Tracker** and **Tuner** include custom serial interfaces and do not use your computer's valuable COMM ports. The software runs in your PC's "spare time," letting you run other programs at the same time.

The **Kansas City Tracker** and **Tuner** programs are "Terminate-and-Stay-Resident" programs that attach themselves to DOS and disappear. You can run other DOS programs while your antenna tracks its target and your radios are tuned under computer control. This unique feature is especially useful for digital satellite work; a communications program like PROCOMM can be run while the PC aims your antennas and tunes your radios in its spare time. Status pop-up windows allow the user to review and change current and upcoming radio and antenna parameters. The KC Tracker is compatible with DOS 2.00 or higher.

Satellite and EME Work

The **Kansas City Tracker** and **Kansas City Tuner** are fully compatible with N4HY's QUIKTRAK and with Silicon Solution's GRAFTRAK. These programs can be used to load the **Kansas City Tracker's** tables with more than 50 satellite passes.

DX, Contests, and Nets

Working DX or contests and need three hands? Use the **Kansas City Tracker** pop-up to work your antenna rotor for you. The **Kansas City Tracker** is compatible with all DX logging programs. A special callsign aiming program is included for working nets.

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AMSAT-NA can take your order for a Kansas City Tracker/Tuner or one of many Satellite Tracking software packages that support the KCT, such as Quiktrak, Graftrak, and WiSP for Windows. When you order thru them, they receive a Donation in your name towards the Phase 3D Project. Their telephone number is 301-589-6062.



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Advertising Office: AMSAT-NA Headquarters, 850 Sligo Avenue,
Suite 600, Silver Spring, MD 20910-4703.

The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly
(Jan, Mar, May, Jul, Sep, Nov) by AMSAT-NA, 850 Sligo Avenue,
Suite 600, Silver Spring, MD 20910-4703. Telephone:
301-589-6062, fax: 301-608-3410. Periodicals postage paid at
Silver Spring, MD, and additional mailing offices. Postmaster, send
address changes to The AMSAT Journal, 850 Sligo Avenue, Suite
600, Silver Spring, MD 20910-4703.

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and efforts to produce The AMSAT Journal.

Apogee View

Thank You!

First of all a big "thank you" to all who have volunteered their services following the request in the January/ February Apogee View; AMSAT appreciates your help and assistance. The offer is always open, and if you would like to become a part of the leadership of AMSAT-NA don't hesitate to contact me or other AMSAT-NA officers.

As you read this Dayton will just be over and we will be once more looking forward to the launch of Phase 3D, and the ISS service module. One thought that has occurred to me concerns the number of satellite operators that need some help in organizing a station. Many people contact me with questions about satellite equipment, what is the best, what price, how to connect, etc. and I am sure that the number of similar requests will grow as we get closer to launch time. Now is the time for the Area Coordinators to be front and center. These ladies and gentlemen of AMSAT have the capability to advise on many of the questions that will be asked. While as individuals, they may not be able to advise on the detailed technical differences of various pieces of equipment, they will be able to relate to their own system and to items that work for them. AMSAT Area Coordinators are at the Operational Front Line of our interface with the Amateur Radio Operator, and have the support of the Board of Directors for the fine work that they do.

At the end of March, this year, Vice President of Human Space Flight, Frank Bauer led an AMSAT-NA and ARRL delegation to the Amateur Radio on the International Space Station (ARISS) meeting at the European Space

Agency Headquarters in the Netherlands. This meeting was well attended by European and North American Delegates and many agreements were agreed in principle.

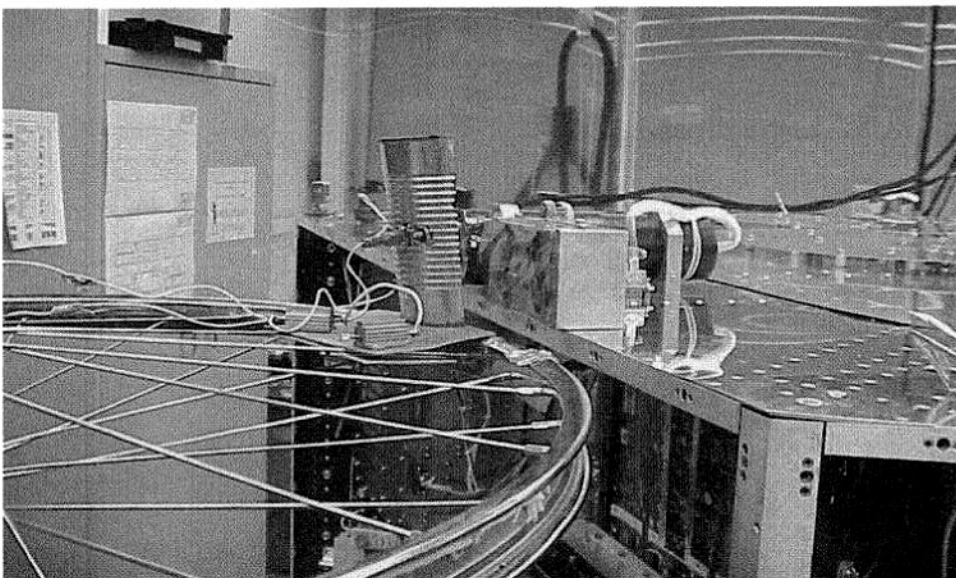
Unfortunately without the presence of delegates from Russia and Japan, it was impossible to get a total consensus on the items discussed.

The minutes of this ARISS meeting will be published in the next issue of *The AMSAT Journal*, and discussions will take place with the absent delegates to ensure that there is a total consensus. Meanwhile arrangements are going ahead to provide the necessary hardware and astronaut training, which will enable ARISS operations to take place at the earliest opportunity after the launch and commissioning of the Russian service module later this year.

Delegates to the Netherlands meeting were able to enter a duplicate of the European supplied ISS *Columbus* module that is to be used for training the Astronauts. The delegates were taken on a tour of the ESA laboratories to see their latest impressive testing equipment and satellites which were in the process of being built and tested.

As reported in this column in the January/February issue, the annual dues for AMSAT-NA are about to increase effective 01 July 2000, the new rates will be U.S. \$36.00 per year, Canada \$41.00 per year and all others \$45.00 per year. (All rates are in U.S. Dollars.) Until July 1st you will be able to join or renew for one or more years at the current rates. This is the first dues increase in twelve years.

73 de Robin Haighton, VE3FRH, Executive Vice President ■



Phase 3D Integration Manger, Lou McFadin, W5DID informs us that Chris Karpinsky, KB2HJN is the winner of the *What Does this Do for Phase 3D Contest*. See page 28 for details on Chris' correct answer.

[continued from page 1]

- Continuing high popularity of AO-27 for handheld FM voice comms.
- Growing popularity of UI digipeating via *Mir* through 1999
- Activation of UO-14 for FM voice repeater mode in February 2000
- Experimental UI digipeating via a 9600 Baud Packet Satellite
- FM VOICE repeating via SUNSAT SO-35 throughout 1999
- Recent activation of a SUNSAT SO-35 for UI digipeating
- Dayton 2000 introduction of the up-graded Kenwood TH-D7 HT!

Since any FM transceiver can be used for two-way satellite FM voice communications via AO-27, UO-14 and SO-35, this article will concentrate on the more esoteric use of HT's and mobile radios in live TEXT messaging applications, not the more widely known VOICE applications.

Since the use of short, one-line messages for rapid real-time communications via packet gained popularity within the APRS environment, I have named this general architecture for using satellites to enhance the range of these communications as ASTARS, for APRS Satellite Tracking and Reporting System.

ASTARS is an Amateur Radio Mobile Tracking and Communications System for

Reporting position, status, and messages to and from mobiles in distant locations via amateur satellites using off-the-shelf amateur equipment. Since there are a variety of satellite modes, modems and bands, the ASTARS concept has evolved from this same variety of digital communications schemes.

1200 Baud PSK ASTARS was a system called TRAKNET [1] which was presented at the 1998 and 1999 AMSAT conferences as a 1200 baud mobile satellite network using AO-16, LO-19 and IO-26 which have been authorized for live APRS tracking and position reporting. PSK ASTARS was used by 16 stations[2] during the annual Army/Navy Football run [3] and other special events. It is a very viable capability for stations with PSK TNC's or using KA2UPW's sound-card uplink capability [4]. Since all birds share the same 145.900 uplink, the only remaining need is to set the UI-DIGI callsign on all birds to the SAME generic call, so that mobiles do NOT need to change any settings between satellite passes and therefore get over 12 passes a day for this three-satellite constellation.

1200 Baud AFSK ASTARS was demonstrated many times during experiments with the Space Station *Mir* [5] packet system and SAREX [6]. These experiments culminated in the June 1999 week long experiment via *Mir* which used the new Kenwood TH-D7 with built in 1200 and 9600 baud TNC's to demonstrate two-way self-contained APRS communications via *Mir* at 1200 baud. During this test [7], over 55 stations conducted 2-way HT-to-HT message

communications. Although some think that 1200 baud PACKET via space is obsolete, it is PERFECT for HT-SATELLITE communications via a digipeater. The 9dB advantage of 2m to a handheld 2m antenna cannot be beat on any other band. Satellites with this capability are SAREX, ISS, *Mir*, and recently activated modes on SUNSAT.

The existing TH-D7 can also be used with a laptop (and small UHF beam) for any 9600 baud ASTARS activities too (but only UP or DOWN, not both).

9600 BAUD ASTARS the latest form of live digital satellite communications became a reality when Kenwood introduced the 1200/9600 baud APRS data mobile radio, the TM-D700A [9]. This dual band data radio with built-in TNC's and front panel APRS displays made it possible to send and receive the very short APRS style communications via any 9600 Baud PACSAT if digipeat is enabled. Unlike the 1200 baud PSK Packet Satellites, the 9600 baud Packet Satellites use FM radios and FSK. Thus, the D700 radio is an off-the-shelf satellite data terminal ready for ASTARS and it needs NO PC or other accessory. It can send and receive all data on the radio front panel with only a 2m 20" whip as the antenna!

Secondly, the presence of the Internet that makes possible the linking together of multiple disparate downlink sites allows a tremendous gain in reliability through space and time diversity reception. These stations, called SAT-Gates (Satellite IGATES) combine all packets heard into the existing worldwide APRS infrastructure

CALL	STATUS	ICON	GRID	DIST	CSE/SPD	COMMENT
WB4APR-9	Bob at work	HT	FM19sa	101mi N	Parked	Off duty
WS4Z	ws4z@amsat.org	Car	EM43uh	847mi SW	Fixed	Special
KB8GVQ-8	Testing D700	Jeep	EN91dk	320mi NW	000/000	Off duty
K2SAT	Using APRStk	Dish	EM62bw	763mi SW	Fixed	Committed
KA1RRT	QRZ	Boat	EL87nw	849mi SW	043/008	Enroute
N5SUB	Lookin for Tfc	Van	EL29FX	1251mi SW	075/000	CUSTOM 3
KB2WQM-7	At da beach!	AMSAT	FM29PE	96mi NE	000/000	Off Duty
K5WH-14	@amsat.org	Truck	EL29fx	1252mi SW	178/000	In Service

Table 1. Example of Mobile User Data.

(APRServe)[10] for delivery to any compatible APRS station in the network.

This paper describes ASTARS, beginning with its limitations, expected operations scenario, the D700 set up for mobile operation, linking traffic to/from the worldwide APRServe system via SAT-Gates, how the SAT-Gates operate, and how the terrestrial APRS system can distribute satellite access times to the mobiles using minimum bandwidth on the terrestrial system.

EXAMPLE: The APRS Mic-E format used by the Kenwood radios transmits all of the following information in only 9 bytes except for the STATUS text which adds 1-for-1 to the length of the packet. Thus, a lot of information can be transmitted in less than 0.5 second per mobile. Table 1 provides as an example, a pass as received on a Mobile D700.

Limitations

The 9600 baud UPLINK is trivial to do and works fine from any mobile omni antenna. But the overall system has several limitations that drive the operational scenario:

- Due to multiple use of these satellites and frequencies, unnecessary congestion on the uplink is to be avoided.
- The weak UHF downlinks can only be received for the central 2 or 3 minutes or less of an overhead pass on an omni mobile whip.
- Longer pass times are possible with a cumbersome 4 element beam or by using 2 meters as the downlink band.
- Such overhead passes occur only once or twice in the morning and the evening per day per satellite at USA latitudes.
- Doppler tuning of +5, 0 and -5 kHz is necessary in the middle of the pass for an omni antenna to get the longest possible downlink times.

APRS Messages

For satellite operators unfamiliar with APRS messages, it should be understood that an APRS message is a single LINE of text. Most messages stand alone, but are occasionally strung together if it won't fit on one line. Figure 2 is a photo of a 15 byte

message received on the TMD700 radio (the maximum length is 64 bytes).

Similarly, an EMAIL message is also only ONE LINE and the one line INCLUDES the full email address. This forces brevity! Here is e-mail I transmitted from my D700 mobile enroute to work this morning. Notice that the SINGLE packet entered into the D700 was simply:

TO:EMAIL :wb4apr@amsat testing delivery via pacsat from my van enroute to work.

Yet, here is how it was received by my e-mail system after being SAT-Gated to APRSserve and from there, picked up by the EMAIL Engine at WU2Z's and shipped out as regular e-mail:

Date: Mon, 7 Feb 2000 07:58:09 -0500 (EST)

From: WB4APR-9@unknown.net

To: wb4apr@amsat.org

Subject: APRS Message from WB4APR-9

testing delivery via pacsat from my van enroute to work.

Message received by MacAPRS IGate station WU2Z

Located in NO BRUNSWICK, NJ

APRS path = WB4APR-9 APK101, SUNSAT*:

Operations Scenario

To develop a viable satellite communications system that can communicate between mobiles and also to/from the worldwide APRSserve [10] system within these limitations, the following operating scenario is recommended.

- To recognize satellite mobile stations, please use a -3 SSID and save this in a PROGRAM MEMORY for use only while operating via the satellites. This is so the SAT-Gate can distinguish traffic for your satellite mobile separately from terrestrial traffic pending.
- Due to the very sparse access periods, the mobile uplink objective should only be to get ONE position reliably relayed per satellite pass. It appears that a one-minute rate per mobile can guarantee such success... without overkill.
- During a pass, mobiles can uplink any outgoing messages. The fixed once-per-minute message rate and 5-times-timeout of the TM-D700, is just about right.
- If the SAT-Gate has any return traffic for you, it will transmit that traffic only during the central 2 minutes when the satellite is at its closest distance to your station.

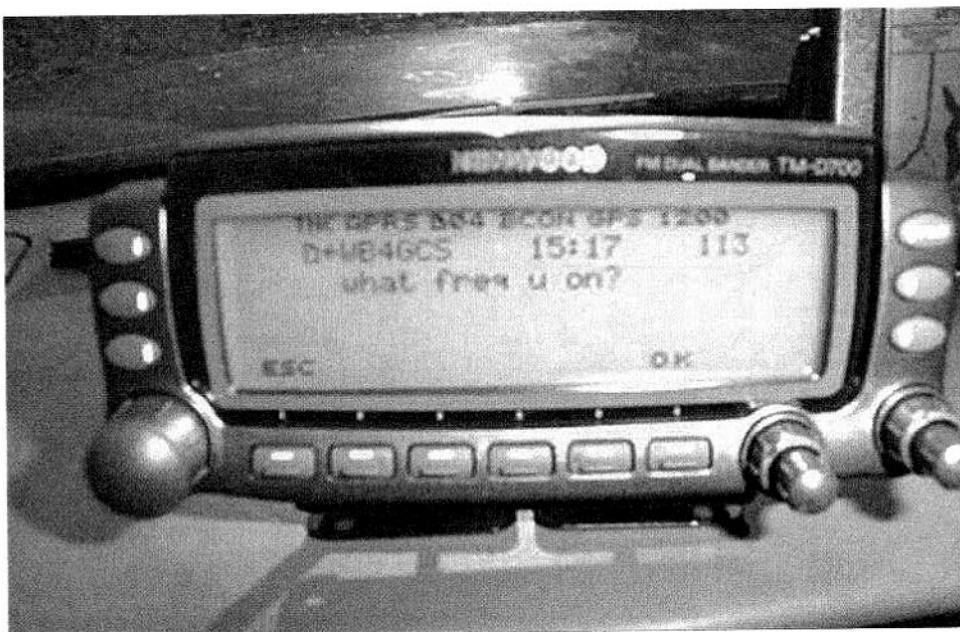


Figure 2. 15-byte APRS message.

- If you are using a beam antenna and can copy more of the pass, then you can signal the SAT-Gate to try longer in the pass by including "QRZ" in your STATUS, or by sending CUSTOM MSG 3

Sat-Gate Operations

Mobile-to-mobile communications works without any special considerations on the satellite or on the ground. But the more useful application is sending and receiving messages to any other APRS station via SAT-Gates that are monitoring the satellite downlink and serving as gateways into the world wide APRS system. These SAT-Gates perform the following functions:

- Monitor the downlink and capture all calls in the coverage area
- Monitor APRS and capture MESSAGES for these calls
- Deliver these messages at a "fair" rate under these conditions:
 - The satellite is within 1400 km (above 30 deg) to mobile
 - It sees "QRZ" in the Mobile's STATUS text
 - It sees CUSTOM-3 comment. (Easier to enable from the keypad)
- Transmits these messages redundantly until digipeated three times.

Omni No-Track Sat-Gates

With nothing but the same 20" mobile whip antenna over a suitable groundplane, any TM-D700 radio becomes a no-track SAT-GATE downlink receiver. The WHIP will bring in signals whenever the satellite is above about 20 degrees which is about six minutes for a nominal high-elevation pass. Note, a 20" whip is a $\frac{1}{4}$ wave antenna at the 2m uplink, and $\frac{3}{4}$ wave at the 435 MHz downlink. The $\frac{3}{4}$ wave antenna has high elevation gain (almost 8 dB) ideal for this application.

But the $\frac{3}{4}$ wave vertical is not good on the horizon, but unlike any previous amateur satellite activity, we can combine the outputs from a dozen such stations nationwide and the result is over a 99.96% chance of capturing every packet over the USA! Even if only four stations at any one time have the bird in view of their station and even if they only have a 60% chance of decoding each packet, their combined probability is 98%. But if the original packet is replicated TWICE, then this probability becomes 99.96 percent! A certainty!

Figure 3 map shows how six ground stations limited to solid downlinks only while the satellite is above 30 degrees using only 20" whip antennas can see the satellite anywhere over the USA. Note, the signal above 30 deg is +7 dB closer and maybe +3 dB in the gain lobe of the $\frac{3}{4}$ wave whip for an equivalent of +10 dB. Thus, no packets will be lost.

Actually, we would like to see a dozen such downlink stations to provide the added reliability to 99.96%. This is easy to do. We already have dozens of similar APRS I-GATES. All they need to do is add a D700 at their station and a whip antenna. To handle multiple satellites, the APRStk program (see below) now AUTO TUNES for any satellite in view! Even an \$88 Alinco HT can be used as a downlink station [11].

Base Station Operations

Since the UHF Packet Satellites are shared assets with many existing amateurs using the PACSAT protocol and File/BBS system we only want to encourage this message system for use by mobiles who have no other means to communicate from distant locations. For this reason, we do not encourage base station operations other than SAT-Gates or for direct contact with a mobile if needed. A Mic-E style packet from the D700 is only 9 bytes long, compared to a WinAPRS typical 80 byte position report.

The latter are strongly discouraged. Stations using software other than the D700, should only operate in APRS compressed mode and minimize their STATUS text. Beams on the uplink for this application are also NOT desired. To use this mode, we must keep our ERP to 50 watts to an omni or equivalent to remain below other higher priority users.

Satellites

There are many 9600 baud Packet Satellites in orbit and on the drawing boards. Most use the PACSAT protocol which is very efficient for delivering large files to many users. Our presence on the uplink is in competition with others uploading to the bird and thus should be minimized and used only where mobile satellite communications are required.

Thus, The *ideal* satellites for us might be an imaging satellite which may have megabytes on the downlink, but the uplink might be relatively empty except over command and uplink stations. These command stations typically run 100 watts to 13 dBi antennas and thus have a 16dB margin over any mobile. Due to this power differential, we hope the satellite assets can be reasonably shared between the two applications.

Satellite Tracking and Pass Predictions

APRS mobiles must only uplink during the middle of a satellite pass and at no other

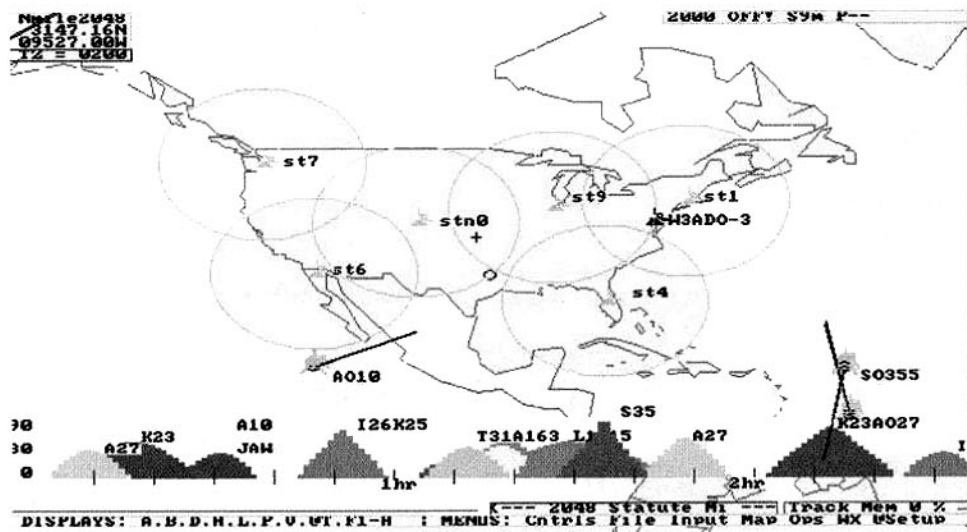


Figure 3. Satellite pass over APRS stations.

times to keep the uplink clear of non-essential transmissions. To this end, I have added Satellite tracking to APRSdos in the form of APRStk.exe. It must be run within an existing APRSdos file structure to get all the maps. It presents the satellite predictions on the APRS map and will auto-tune the Kenwood radios including Doppler. It is available zipped up as a complete system for download from:

<ftp://tapr.org/aprssig/dosstuff/APRSdos/aprstk.zip>

APRStk can also distribute via the terrestrial network sufficient pass information so that other travelers are aware of pass times long before they drive out into the wilderness. Figure 4 provides a screen shot of the APRStk screen (zoomed out to the 1024 mile scale).

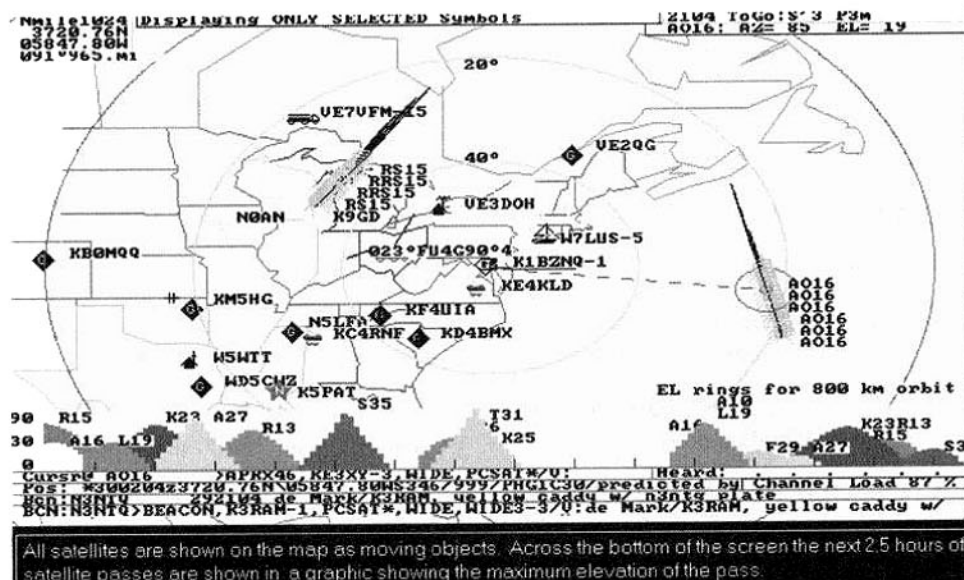


Figure 4. APRStk screen zoomed out to 1024 mile scale.

But for the mobile traveler not using a LAPTOP, fortunately we have an excellent way to send special PASS INFO directly to the mobiles' radio. APRStk can transmit the schedule to the TH-D7 or TM-D700's DX-LIST. Thus, our mobile satellite users can get the PASS info they need without lugging along a laptop. This shows you what the Handheld TH-D7 HT will capture and display about the satellites. First is the DX-SPOT list (Figure 5) showing that there are three satellites UO-22, AO-27 and UO-14 coming up in the next 80 minutes.

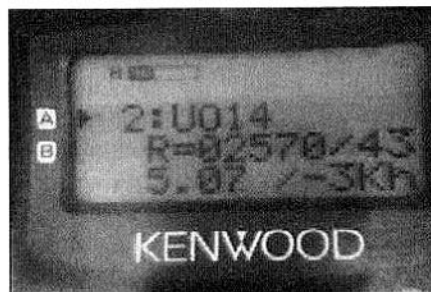


Figure 5. DX-SPOT list showing UO-22, AO-27, and UO-14

The next two screens (Figures 6 & 7) show when the satellite is in view. They show the Range, Azimuth, Frequency, Doppler and Distance to the satellite. Just perfect for aiming your handheld antenna. For more details on this resource for non-PC distribution of satellite information, see the WEB site: <http://web.usna.navy.mil/~bruninga/satinfo.html>

TM-D700 Settings

Here is a list of the minimum setups for the new Kenwood TM-D700 data radio for front-panel-to-satellite mobile communications via a digipeating Packet Satellite, (using my data via SUNSAT as an example):

- APRS-MYCALL - WB4APR-3
- APRS-MYPOS - 3859.11N 07629.11W
- APRS-STATUS TEXT - @amsat.org (my email address)
- APRS-STATUS RATE - 1/1

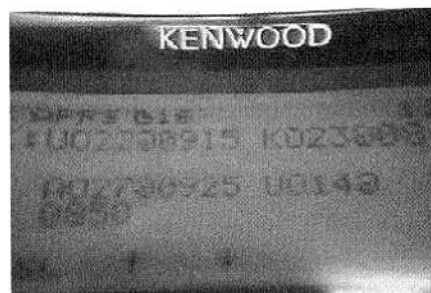


Figure 6. Satellite in view.

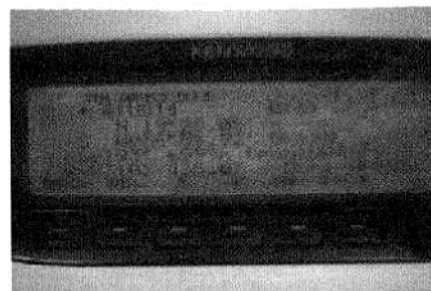


Figure 7. Satellite in view.

- APRS-PACKET PATH - SUNSAT or appropriate other digi call.
- APRS-PACKET TX - AUTO
- APRS-TRANSMIT-RATE - 1 min
- APRS-DATA BAND - A:RX B:TX
- APRS-PACKET-SPEED - 9600
- APRS-MSG-GROUP - Add "*" to the list so you can see all msgs
- APRS-POSIT-LIMIT - 0 (so you don't filter out DX stations!)
- TNC-DISP-KEY MODE - MODE3 (so you have APRS functions handy)
- Tune band A to 2m DOWNLINK and band B to UHF UPLINK
- Then SAVE as PROGRAM MEMORY #N, so you can instantly get to it.

Transmitting

In APRS mode, the TM-D700 radio does not set the internal TNC to FULLDUPLEX. Thus, while your band B is receiving data the radio will not transmit. Understanding this problem will be your key to success. Here are some ways to force a transmit:

- Set to AUTO and then QSY the downlink long enough to silence rcvr
- Set to PTT and kerchunk xmtr when Posit BECN is ready...

- Set to auto and QSY to ignore downlink.
- Set to downlink and never transmit except during fades.
- Operate PACKET mode with laptop doing APRS (With FULLDUP ON)
- Use APRStk
- Purchase the new TH-D7 (G) which has the DCD IGNORE COMMAND...
- Upgrade your TH-D7 to the new firmware

Antennas

Because of the short coax run, and no need for a PREAMP, in a mobile, a simple 20" 2m WHIP antenna is an ideal mobile OMNI antenna for both transmit and receive. On UHF receive, the antenna is a $\frac{3}{4}$ wave monopole with a lobe at high elevations which is ideal for the satellite downlink near the center of the pass (Figure 7). My D700 will capture packets when the satellite is above 25 to 30 degrees for a few minutes. But to gain the full downlink, a handheld 4 element or so UHF downlink antenna rotated in AZ, EL and polarity is required. Much experimentation in this area is needed. Figure 8 is a plot of the EZ-NEC produced gains of three whip antennas including the path loss due to range. My $\frac{3}{4}$ wavelength antenna actually picks up the UHF satellites at about 20 degrees. And for the VHF SUNSAT downlink, the signal is usually

horizon to horizon. Better shown as Figure 9.

Tuning

Tuning the UHF downlink is trivial to do by ear. Although 9600 baud data sounds just like open-squelch noise, it does have a *quality* to it that can easily be heard by ear when the receiver is not centered in the data bandwidth. All UHF passes begin at +10 kHz and move down in 5 kHz increments down to -10 kHz. It only takes a fraction of a second to test QSY to hear if it is time to tune or not. Eventually you can hear when it is time. For omni-directional antennas where you won't hear the satellite on the distant horizon, then start at +5 kHz and move twice to -5 kHz during the brief pass.

Effectiveness

The APRStk screen shot provide as Figure 9 shows the ANALYZE command which plots the packet count over time along with the elevation angle. This is useful to compare the relative performance of your station. Notice how KO-23 has just completed a pass and the packets began being received on my 20" $\frac{3}{4}$ wave omni antenna at about 30 degrees and then it was received all the way down to about 20 degrees. The 5 evenly spaced spikes are local TNC reset data that occurs every time the THD7 is commanded to QSY down 5 kHz. Two other spikes are spurious re-tunes and I caused the big spike by QSYing the radio to 144.39 MHz for a few seconds before I realized I wanted to save this plot. These peaks are not packets from the satellite. The TM-D700 does not do these spurious data, since it does not reset the TNC every time you send a QSY command.

Conclusions

With the Kenwood and Alinco mobiles and Handhelds with built-in 9600 baud TNC's, it is time to start looking at our amateur satellites as a means of real-time worldwide digital communications for HAMS on the go. With the front panel displays of the Kenwood TM-D700 and TH-D7 we can even think in terms of HANDHELD WEB VIEWERS. That is exactly what the APRStk software does when it paints on the front panel of these radios via the APRS channel the SCHEDULE of satellites due in the next 80 minutes and/or when it transmits the current position of the satellite for display in RANGE and AZIMUTH on the radio's screen. I hope you will see the vast potential that is opening up before us.

Elevation Plot of Vertical Whips at 435 MHz (includes Range Gain)

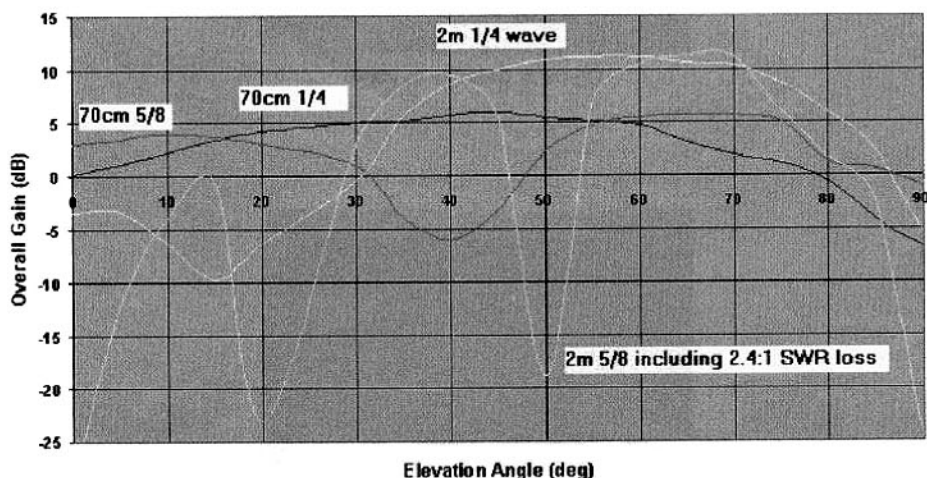


Figure 8. EZ-NEC gain for three antennas.

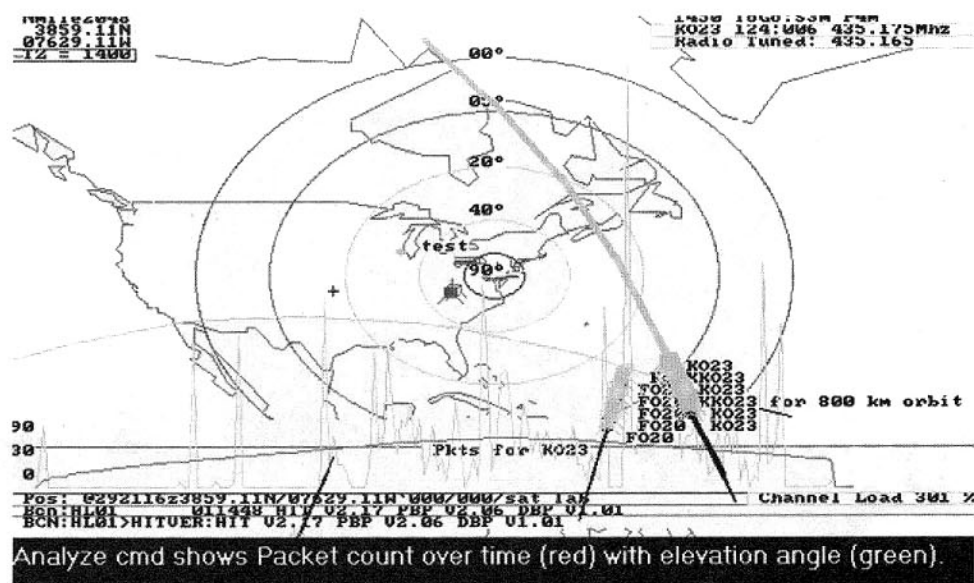


Figure 9. APRS effectiveness.

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1. <http://web.usna.navy.mil/~bruninga/traknet.html>
2. <http://web.usna.navy.mil/~bruninga/fbsatsum.txt>
3. <http://web.usna.navy.mil/~bruninga/fball99.html>
4. <http://members.aol.com/dquagliana/upw/index.html>
5. <http://web.usna.navy.mil/~bruninga/mirex.html>
6. <http://web.usna.navy.mil/~bruninga/sarex.html>
7. <http://web.usna.navy.mil/~bruninga/mir-ht.txt>
8. <http://web.usna.navy.mil/~bruninga/aprsat.txt>
9. <http://web.usna.navy.mil/~bruninga/TM-D700A.gif>
10. <http://web.usna.navy.mil/~bruninga/www.aprs.net>
11. <http://web.usna.navy.mil/~bruninga/88-9600.txt> ■

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RS-13 and the DX Anomaly - Part 2

John Branegan, GM4IHJ (gm4ihj@branegan.demon.co.uk)

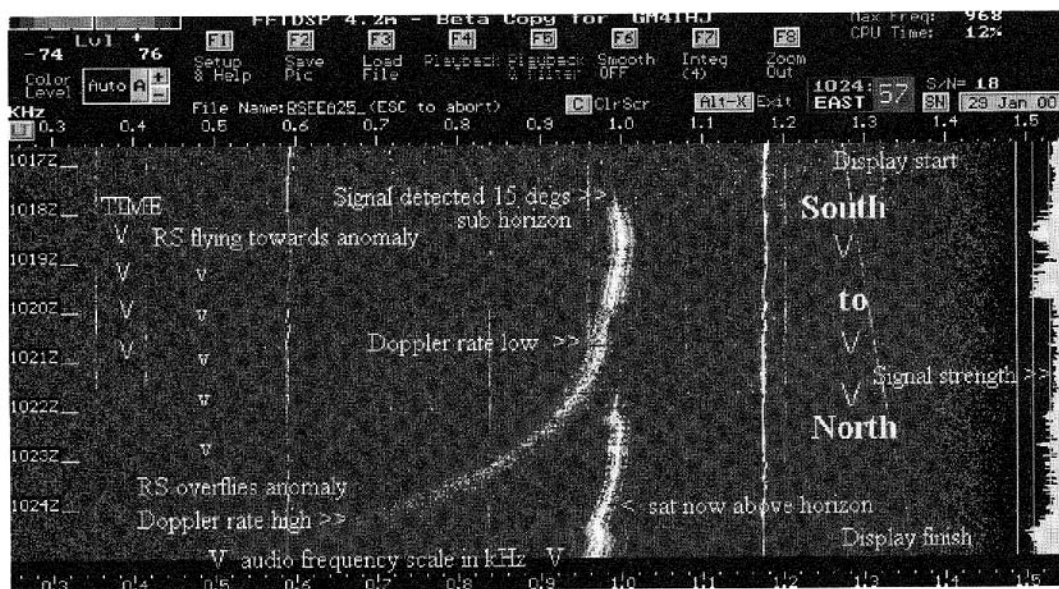


Figure 1. RS-13 Audio Signal recorded 1017UTC to 1025UTC on 29 January 2000.

In Part 1, titled "RS-13 and the 40N DX Anomaly," (see the January/February 2000 issue of *The AMSAT Journal*) satellite signal Fast Fourier Transform (FFT) DSP audio spectra were shown to produce evidence of anomalies in the ionosphere to the south of the UK. Anomalies which seemed to be in

accord with the mid-latitude terrestrial 10m and 6m ionospheric features which can provide DX radio communication paths between Europe and America and other similarly spaced temperate northern latitude sites around the world, when the normal great circle communications paths are not available. Part 1 was based on a study of

satellite orbit passes descending past Scotland on north to south tracks. This article presents a review of reports on the use of satellite tracks coming in the opposite direction, south to north ascending, clarifying some of the questions raised by the previous paper.

The original review, Part 1, was based on records of descending orbits heading southwards past the Scottish base station at 56.2N/3.6W, in October 1999. By late December 1999 and through January 2000, RS-13 was coming past Scotland on ascending orbits proceeding from south to north. As before the evidence of the anomalies appeared on the FFT DSP audio spectrum display, only when the satellite was some way to the south of Scotland, i.e. usually before the satellite came above the Scottish horizon (Figure 1). (Please note that the computer display of the spectrum in Figure 1 is not easily reversed, so south always appears at the top of the display.) Orbits chosen for recording were those passing almost overhead the station, i.e. those orbits in which the satellite footprint and sub-horizon anomaly activity coverage, extended farthest south.

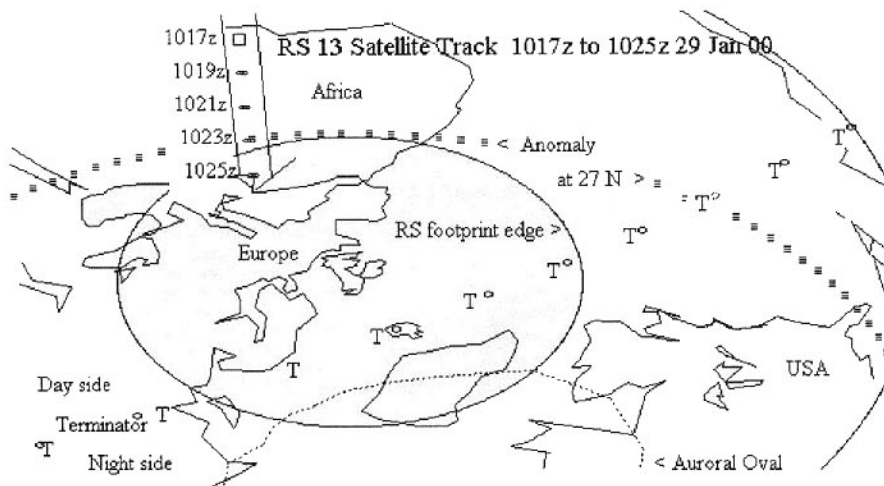


Figure 2. Great Circle map showing RS-13 track 1017Z on 29 January 2000.

A great circle map showing the track of the satellite whilst Figure 1 was being recorded is appended as Figure 2.

A side view of the earth and the ionosphere, drawn to scale is shown as Figure 3. This figure shows a suggested path for the anomalous propagation and the later direct propagation.

Comparison of Descending Versus Ascending Orbit Records

Figures 4 and 5 are the two sides of the coin. They show satellite signal spectra on two tracks along the same longitude and across the same range of latitudes. Figure 4 was recorded on an descending orbit, while Figure 5 was recorded a little over 2 months later on an ascending orbit. The record in Figure 5 has been reversed in order to show the degree to which the Doppler feathers produced by the anomaly are faithfully reproduced. This suggests that given roughly similar conditions of solar flux anomalies in this latitude range can be expected to appear day after day. With the RS-13 satellite HF beacon giving a clear indication of their presence.

Latitude Band Covered by Anomalies Seen from Scotland

The record at GM4IHJ's 56.125N latitude station, is clearly limited in regard to how far to the south it can detect the anomalies. Best results to the south are obtained when the satellite is ascending or descending on a track which comes overhead or, nearly overhead the station. On these orbits it has

been possible to detect anomalies as far south as latitude 23N, i.e. an anomaly horizon distance of about 33 degrees. Stations observing from lower northern latitudes will perhaps be able to detect anomalies below 23N. But whilst no southern limit for anomalies can be suggested by these results, it is clear from records of over 60 orbits, that anomalies above 45N latitude are very rare (Figure 6).

As will be obvious from most of these records, the anomalies indicate a signal return which even at 29 MHz is weak and tone 4 auroral at best. It will be interesting to see if further experiments when solar flux is higher than the 130 to 170 units present on most days when records were taken, display stronger Doppler feathers indicating a possibility for back scatter propagation supporting the highly desirable 50 MHz DX that most radio amateurs are looking for.

Multiple Anomalies

As Figure 7 shows, several anomalies can be present at the same time. There is some as yet inconclusive evidence that these bands of concurrent anomalies are only present when solar flux levels are high.

Summary

It is clear that the 29.485 MHz beacon on RS-13 is an excellent tool for propagation research. The title of part 1 with its mention of the 40N DX anomaly, clearly understated the latitude spread of these anomalies. It should be possible using RS-13 to prove that this belt of anomalies stretches around the world. Equally important southern hemisphere stations may be able to test for the presence of similar ionospheric anomalies in their hemisphere. Further experiments in the northern hemisphere should perhaps concentrate on examining whether the strength of the anomalies

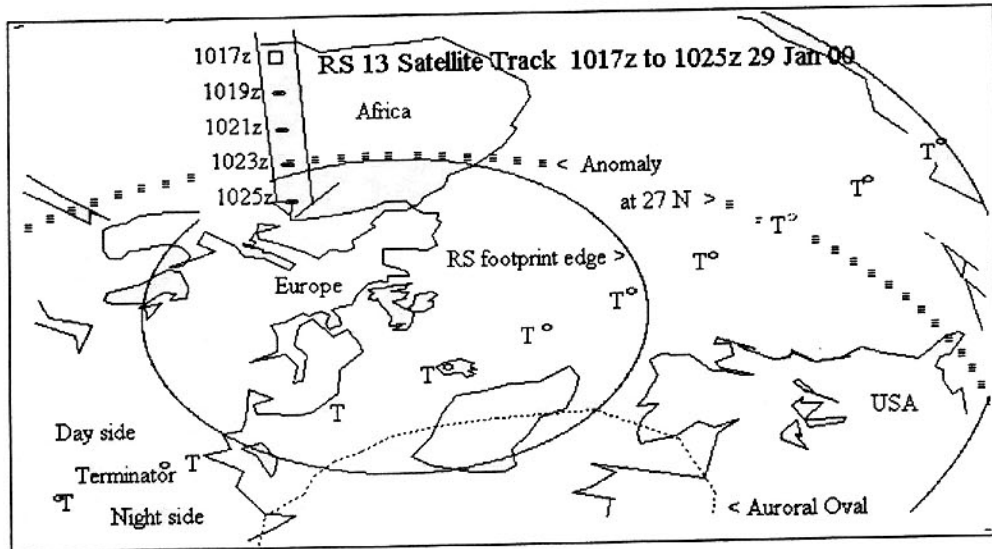


Figure 3. Satellite coming towards Scotland from the south.

Satellite coming towards the station from the south

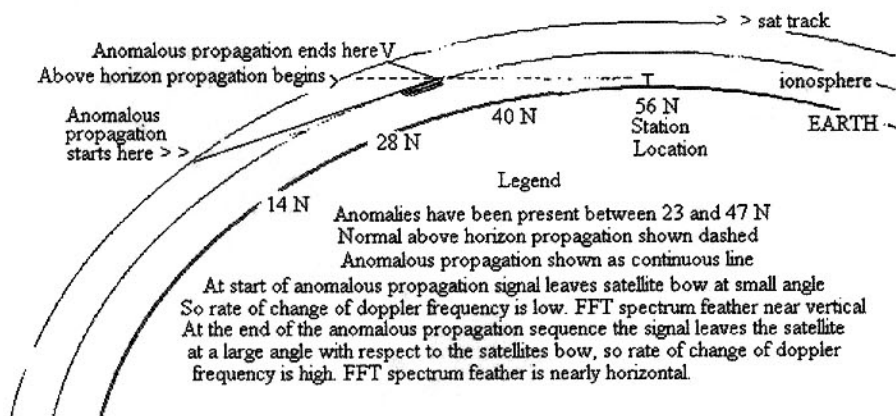


Figure 4. RS-13 Descending Node, 18 Oct 1999.

revealed by RS-13, can be used to gauge the likelihood of non-great circle 6m DX.

In the course of these studies it has become clear that Doppler feathers and other features also occur at times, when RS over-flies the auroral oval. While at far greater range, anomalies are often seen on signal received in Scotland from RS-13 when it is descending over latitude 40N over the Far East, and even farther south over the Southern Oceans. These events will be the subject of further study. ■

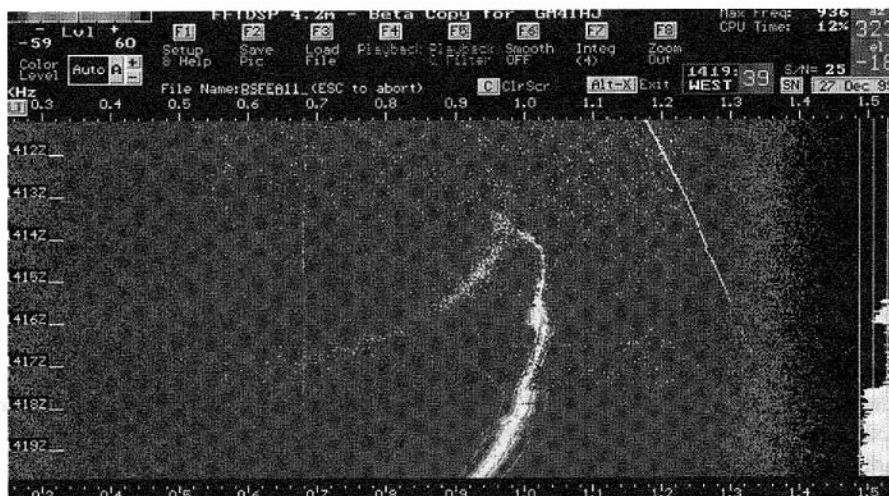


Figure 5. RS-13 Ascending Node, 12 Dec 1999.



Figure 6. The area to the south of Scotland where anomalies are found.

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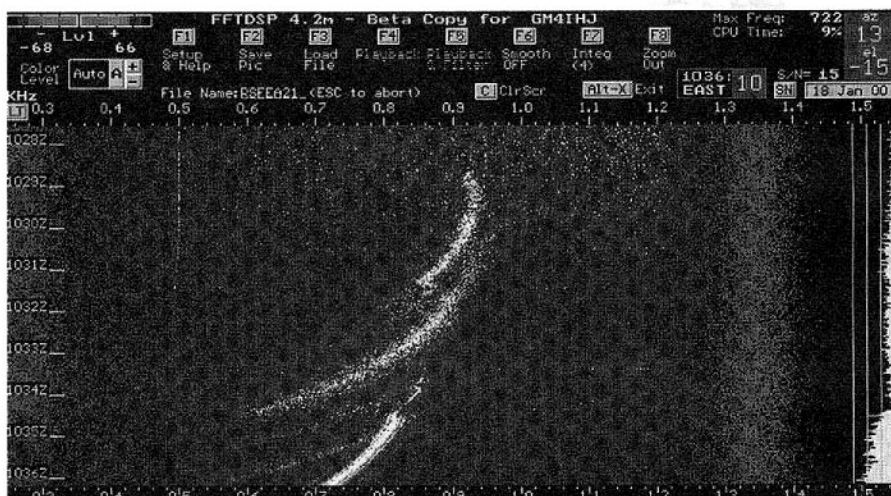


Figure 7. Multiple anomalies located between 37 and 45 N latitudes.

Yet Another Exciter for 23cm Work: Embedded Microcontrollers

Allan Copland, GM1SXX
(gm1sxx@amsat.org)

What's going on in GM1SXX's shack/dungeon this time? Well, for a start, I've just completed yet another UNVLO2 local oscillator unit. This one was built 'by the book' using the instructions (That'll be a change - LA2QAA!) to produce another high quality oscillator strip. This will be used initially as a test transmitter, so I can play with some DIY receive converters for 23cm. (Yes, I know Phase 3D won't have a 23cm downlink but I want some design experience.) This new local oscillator is eventually destined to be the exciter for a 23cm beacon.

Embedded Controllers

This time, I'd like to mention the subject of *embedded* controllers. You may be thinking, what do embedded controllers have in to do with amateur satellites? For an answer, take a look at the Stensat Internet pages. Although Stensat seems to be a lost cause, I imagine the use of embedded controllers in spacecraft will soon become very popular. They have some overwhelming advantages both on the ground and in space over conventional microprocessor systems. Best of all is their simplicity and low power

consumption. They may even have a place in your shack or your shirt pocket. Embedded controllers come in many shapes and sizes from simple lowly chips *embedded* in smartcards to some fairly sophisticated devices used in instrumentation and the like. My favorite range of controllers are those from the Arizona Microchip stable, the well known and highly respected PIC microcontrollers. Stensat made use of one of these devices. So, what do they have to offer the Radio Amateur? Easy, they are simple to use, simple to program, cheap, consume peanut power and there are a whole load of free software tools available over the Internet to help you get the most from them. Their uses in the shack are limited mainly by your imagination, and your ability to write suitable code to run on them. I chose the PIC over other systems for one reason only, cost. Both of the chips themselves and the development systems needed to produce a working system.

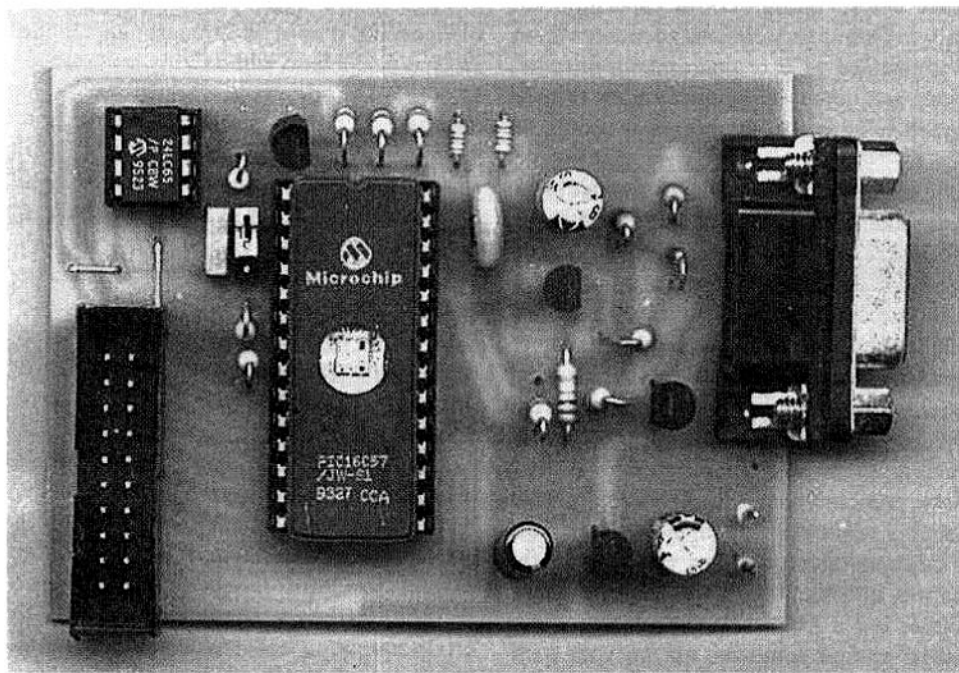
If the idea of programming in assembler is a big turn-off for you, don't despair. There are compilers available for both BASIC and C. Some of them free of charge, to make life easier for you. The makers also host an

excellent website full of information and example code. For those familiar with processors such as the Z80, 6502 and the like, the Arizona Microchip PIC will come as a big shock. It has everything you need to make a simple computer right there on a single chip. Memory, I/O, system clock and analog to digital converters on the *smarter* parts such as the 16C74 chip. You only need supply a simple clock (crystal or cheap resonator) and a reset circuit (one resistor and one capacitor) to have the most basic working system possible. Oh, and they also cost buttons and a complete system is small enough to fit inside a cigarette packet. Need more memory than the PIC provides? Simple ... add a cheap serial EEPROM.

I've used these chips for such things as generating CW, pointing antennas, measuring and displaying temperatures ... and all using simple programs written in the BASIC computer language. I'm sure you could think of many uses for these versatile cheap devices in your shack. Next time, I hope to include enough information to get you started programming and using these versatile devices. You may not be aware of it but you probably already use equipment with these chips as the *intelligence*. Got a cellular phone? Does your computer have a mouse (of course it does)? Both of these everyday devices make use of *embedded intelligence*. Some of the cheap development systems for the PIC even have LCD driving software, serial interfaces and EEPROM memory already *built-in*.

Intelligence or a Beacon

After completing my new UNVLO2 source, I now needed a CW keyer to partner it. A single chip computer (Arizona Microchip PIC 16C57) running a simple program written in compiled BASIC now provides the keying signal for my new oscillator board. The keyer, just like the local oscillator unit is housed in a PCB cabinet made from shiny double sided PCB offcuts. I'm a big fan of the KISS approach. Keep it simple and make it modular. Unlike LA2QAA, I don't think shiny copper surfaces 'confuse' the electrons one bit  Eventually, I hope to use this system as the heart of a permanent 23cm



23cm Exciter

beacon system to try to encourage more interest in this very useful Amateur Radio band allocation. I'm also working on a suitable low-power PA for the unit. This is a somewhat modified version of G4DDK's well known 23cm 1W PA, which has been described in several publications. For use as a permanent beacon, the output would be filtered, divided by a power splitter and fed to a couple of short quagi antennas to provide the sort of coverage needed.

Other Oscillator Strips

Although the UNVLO2 source has rapidly become my favorite on the grounds of performance, low cost and ease of construction, there are others to choose from. Down East Microwave produces a 'no-tune' single board oscillator and SSB Electronics produce the UEK-3, a Local Oscillator / Receive mixer designed to match their USM-3 Transmit Mixer/PA described in an earlier article.

SSB UEK-3

The UEK-3 is described by SSB Electronics as a Local Oscillator / GaAs-Fet receive mixer. This is a self-contained local oscillator unit, capable of covering 1.2-1.3 GHz with an integrated receive mixer. It can therefore function as an exciter for a transmit mixer or as a receive converter (23cm in – 2M out). This makes it a useful kit for the experimenter. Partnered with their USM-3 transmit mixer, it can provide most of the circuitry for a 23cm transverter system. The downside is that the user needs to provide some form of transmit/receive switching & sequencing.

The UEK-3 can be bought in either ready-built or kit form. I opted for the kit, which as with most things from SSB, comes complete down to the tinplate box, connectors, screws and every last bit of wire. Full marks for attention to detail. The circuit is fairly straightforward (as with most things microwave). A Colpitts oscillator designed around the U310 field-effect transistor couples into a frequency tripler circuit (BFR90A), the output of which feeds a two element tuned-microstrip band-pass filter tuned to 288 MHz.

The filter output at 288MHz feeds two more doubler stages to double firstly to 576MHz and then 1152 MHz. The first doubler uses a BFR90A and the final doubler a BFR91A. The final doubler feeds a three section printed band-pass filter, the center element of which is tapped at the 50Ω point to

provide the high level injection signal at 1152MHz for the receive mixer. Tunable printed circuit (microstrip) filter circuits are employed throughout this design. The UEK-3 will provide +13 dBm (20mW) of drive for your transmit mixer.

The receive converter consists of a PI type input circuit followed by a grounded stub feeding a CFY14, MGF1202 or MGF1402 FET (any of the three types may be supplied) the output of which feeds into a three element band-pass filter tuned to the receive frequency. The local oscillator signal is coupled into the output line from the band-pass filter by means of a short parallel line and an associated 5pF tuning capacitor. The signals are then coupled into gate1 of a dual gate FET, type S3030 in my case, and the f1+f2 mixing product on 2M is selected by another tuned circuit. The complete circuit is fed from a single 9V regulated supply (78L09 100mA regulator). A fair number of 'coffin' capacitors are used in this design both for decoupling (of the microstrip filter elements) and in the receive converter output tuning circuit.

Coffin or trapezoidal capacitors look like little coffins, hence the nickname. They are high quality leadless ceramic devices with tapered sides that sit vertically in slots milled into the PCB. Several different values are supplied with the kit the ones used for decoupling can range from 820 – 1000pF while the ones used in the tuning circuits are 8.2 and 33pF. Don't mix them up! Double check that you have the correct values in place before fitting. Coffin capacitors are easy to fit, but very difficult to remove from double-sided PCB if you make a mistake. The capacitance values are normally printed on the metal part of the capacitor bodies.

The kit is straightforward to build but lacks the printed component overlays used in the UNVLO2. The tuning capacitors supplied are SKY green and black types. The green ones are 5pF max and the black ones are 10pF types. The tuning coils are miniature *canned* Neosid types. SSB recommend tuning up the strip using a voltmeter across the emitter resistor of each stage in succession to tune for resonance. I wish they wouldn't do this. It doesn't work reliably. *Don't* listen to their suggestion. You cannot guarantee that you have set the correct frequency using this tuning method. Either use a frequency counter and diode probe or find someone, maybe your local radio club, who can help you tune the strip up correctly. You may get it *tuned up* by the

max smoke method but don't expect it to be on the correct frequency. If you are a newcomer to UHF/SHF work, you should avoid using this tuning method at all cost.

The two FETs used in the receive converter require proper handling to avoid being destroyed by static charges. Proper ESD precautions are essential. If you don't know how to do this, seek help.

This kit is probably not the most suitable choice for the beginner. It is more compact than the LMW kit and some components are fairly tightly packed. The manual is however excellent and if you can work neatly, you should have no problems. The PCB requires a couple of small pieces filed away where the box sides overlap. This should be done before any assembly work begins. The kit comes complete with a 'wrap around' tinplate box and all connectors (BNC). The connectors also require some minor filing work in order to fit neatly against the PCB. The printed circuit board supplied is tin plated but is not plated through. This means that some component leads have to be soldered to the topside ground plane. The SKY trimmers used are miniature types far smaller than the foil trimmers used in the UNVLO2. They are fairly fragile and can be easily damaged by overheating or by cleaning solvents. Having said that, they are an excellent choice for this type of circuit because of the use of high quality materials in their manufacturing process. The UEK-3 uses standard leaded components throughout, with the exception of the *through board* coffin capacitors. All the components should be fitted as close to the PCB as possible to reduce stray inductance.

Observations

I bought the UEK-3 kit before I discovered the UNVLO2 from LMW Electronics. Construction is not quite as simple as with LMW's offering. The components are more cramped, the trimmers more fragile and there are no helpful printed overlays to help with component placement. Like most SSB offerings, it is capable of good performance when properly aligned. The power output is a bit lower at +13dBm than LMW's oscillator (+15dBm), no great shakes really, but of course you get a 23cm – 2M receive converter included. There is also the matter of cost. The UEK-3 costs more than twice the price of LMW Electronics' UNVLO2 kit. In support, it has to be said that the SSB kit comes complete with everything you need, including a tinplate box and

connectors and you get a receive converter thrown in.

I don't like the fact that the oscillator is fed from the same voltage regulator as the multiplier stages. This causes a degree of interaction when tuning up the strip although once set up, the strip works well.

In my personal opinion, the UNVLO2 oscillator/multiplier strip is not only simpler to build and align, it is more stable and far better suited to construction by beginners, but read the below note. Of course, if you are looking for a receive converter for 23cms, the UEK-3 is a complete solution. It's a case

of horses for courses. You pays your money and takes your choice.

Against this, it has to be said that every single local oscillator kit I've ordered from LMW to date (four kits thus far) have been supplied with missing and/or wrong components. Not one has come with all the correct components, although to be fair, a couple came with extra components. This is bad for beginners who would be very unlikely to have suitable replacement parts lying around. I've had wrong value resistors, missing SMD capacitors and a missing tuning capacitor in one kit. For me, this is a minor inconvenience but for a newcomer, it

would be far more serious. Against this however, it has to be remembered though that the market for Amateur Radio kits is hardly a big money maker. Some of the companies producing kits for radio amateurs do so more out of the goodness of their hearts than any motive to turn a profit. LMW is no exception here. Supporting Amateur Radio is only a sideline for this company so I suppose that one can't be too critical. I like the UNVLO2 source a lot but this lack of attention to detail is not good, especially for inexperienced builders.

73 de AI, GMISXX ■

Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	FO-20	RS-12/13	RS-15	FO-29	AO-27	UO-14	MIR
Catalog Number	14129	20480	21089	23439	24278	22825	20437	16609
Epoch Time	130.6549257	131.8811677	132.1643534	131.8045188	132.1368912	132.6709441	132.1531475	132.768816
Element Set	648	252	273	468	354	808	530	641
Inclination	26.9227	99.0477	82.9249	64.8188	98.5888	98.4122	98.4141	51.6514
RA of Node	332.0572	269.2801	213.224	240.9507	44.8542	191.0558	200.3925	84.2762
Eccentricity	0.6022829	0.0540913	0.0027506	0.0166792	0.0351313	0.0008878	0.0010651	0.0012605
Arg of Perigee	50.2806	139.6872	227.5492	295.7022	323.0295	16.2081	329.8856	287.3509
Mean Anomaly	349.1	224.5664	132.334	62.6765	34.7087	343.9407	30.1717	72.6097
Mean Motion	2.05872361	12.83272695	13.74193604	11.275363	13.52721075	14.28127432	14.30419806	15.64221842
Decay Rate	-0.00000047	0.00000006	0.00000057	-0.00000032	0.00000077	0.0000009	0.00000252	0.00029159
Epoch Rev	12713	48049	46459	22129	18428	34526	53757	81342
Satellite	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23	KO-25	ISS
Catalog Number	20439	20440	20441	20442	21575	22077	22828	25544
Epoch Time	132.1358782	132.1481532	131.7610832	132.1256723	132.611226	131.9985659	132.1777809	132.8299713
Element Set	345	328	338	345	31	948	792	633
Inclination	98.4478	98.4565	98.4565	98.4627	98.159	66.0877	98.409	51.5838
RA of Node	206.6391	208.5836	207.908	209.7767	161.961	88.2367	191.3482	324.908
Eccentricity	0.0011329	0.001135	0.0012111	0.0011986	0.0007464	0.0007506	0.0010598	0.0006457
Arg of Perigee	333.608	331.7607	333.1919	331.3571	319.1298	330.0629	357.6745	177.339
Mean Anomaly	26.4525	28.2962	26.8636	28.696	40.9329	29.9958	2.4374	320.1228
Mean Motion	14.3048611	14.30667472	14.30585195	14.30721807	14.37678312	12.86342602	14.28668377	15.77783821
Decay Rate	0.00000333	0.00000296	0.00000338	0.00000303	0.00000413	-0.00000037	0.00000358	0.0005389
Epoch Rev	53759	53764	53758	53767	46266	36393	31338	8422
Satellite	IO-26	TO-31	GO-32	SO-33	PO-34	SO-35	UO-36	Phase 3D (est)
Catalog Number	22826	25396	25397	25509	25520	25636	25693	999934
Epoch Time	132.1306934	132.1837684	132.1793439	132.1489473	132.1259288	132.1554236	132.0659253	96260.25520000
Element Set	810	329	320	154	196	224	240	3
Inclination	98.4153	98.7231	98.7199	31.4394	28.463	96.4571	64.5615	60.0203
RA of Node	191.1435	208.0362	207.836	103.7438	89.4588	345.436	223.1341	342.7876
Eccentricity	0.000958	0.0003079	0.0001039	0.036512	0.0007188	0.015142	0.0043042	0.6752895
Arg of Perigee	17.2041	165.9513	144.9493	112.9691	231.4824	298.1132	302.9462	180.1221
Mean Anomaly	342.9463	194.1777	215.1754	250.9877	128.5122	60.4828	56.7565	179.5059
Mean Motion	14.28272453	14.22645287	14.22396269	14.24777224	15.05620208	14.41271118	14.73540847	1.51063698
Decay Rate	0.00000303	-0.00000044	-0.00000044	0.00000782	0.00002473	0.00000314	-0.00000157	0.0002
Epoch Rev	34521	9539	9540	8054	8429	6375	5683	2

Observations from Norway

John Hackett, LA2QAA

(la2qaa@amsat.org)

APRN

APRN stands for *Automatic Picture Relay Network* and is very similar to APRS.....Amateur Packet Reporting System. The APRS signaling system is a kind of radio locator using packet radio and GPS satellites. Pacsats have also been used as have the Shuttle missions and *Mir*. APRS was devised by Bob Bruninga, WB4APR of the U.S. Naval Academy in Maryland. APRN is a system designed to integrate the APRS system together with SSTV.

A picture is worth a thousand words so imagine "seeing" who you're in QSO with in real time.

I mentioned the TH-7E hand held transceiver and the VC-1H video communicator in the last issue. The handheld having a built-in TNC is literally *designed* for this new mode of communications as is the VC-1H. In the USA this means of communicating has really taken off and the Internet has lots of sites dedicated to the mode as well as the TH7-E and VC-1H hardware. A good starting point is the TAPR website and follow the various links.

I will now *play* Gipsy Rose Lee and make a prophecy. This mode will revolutionize Amateur Radio. Mark my words.

TRAKNET

In 1997, Bob Bruninga WB4APR of APRS fame proposed TRAKNET, a more efficient use of the APRS system using the Pacsat satellites. Current experiments are being performed by Ham ops with APRS on SUNSAT. (*Editor's Note: See WB4APR's article beginning on page one of this issue.*)

A quick review of the above information, coupled with Bob's TRAKNET proposal ought to fire a few braincells and lead to a "new" mode of communications the commercial BIG BOYS would give their eye teeth for. Pictures in realtime....personal TV links?.....think about it....."see" who you're talking to on Phase 3D. Get those brains in gear! chaps and lets show 'em that AMSAT still leads the way (despite the few impatient moaners)!

UO-14

After being *bullied* by several acquaintances I finally decided to fight the QRM and have a QSO on UO-14, if only to say *been there, done that*. I was surprised at the strength of the signals but *not* surprised to hear a lot of stations using high power on this satellite. Why oh why? When will AMSAT suggest a recommended operating procedure to the national societies so that the non-AMSAT members get to read it? When will the experienced operators suggest to the newcomers that they QRP a bit. When will people learn that there is absolutely nothing to be gained transmitting over the top of another station on FM?

What did you say *capture effect* meant?

Tail-Ending

This is primarily for the newcomer. Quite a lot of people have been trying the FM satellites for the first time and finding the QRM *impossible*. How do I get into the satellite in competition with those using far too much effect and those who feel they must hog the transponder for the entire pass? Many people have tried explaining about power budgets and *gentlemanly* conduct; neither of which has helped at all.

One technique that *does* work is the old **QRP** technique of *tail-ending*. To be a good QRP operator you need to hone your skills.....**LISTEN** and learn the operating habits of the the other operators, most of them have mannerisms.... "errrrr," "hrmmm," etc (a *terrible* security habit for a radio operator). You'll find that there is usually a tiny break between the one operator saying thanks for the QSO and the other operator signing off. This is the time to hop in with your callsign...short, sharp, hot paces **BUT ONLY ONCE**. If you call several times you will only be *drowned* by the other operators calling. Remember the capture effect of FM, only the strongest will get through. And as any *good* operator knows, you don't necessarily answer the chap with the *strongest* signal. You answer the fellow with the **best** signal. If there is a good operator working the satellite he/she will almost always answer the QRP station with a clean signal before answering the one who's splattering like an inebriated chimp.

The trick is to be smart and learn the operating habits of the various operators and to use that tiny pause at the end of the QSO. But of course to do this you must first learn to **LISTEN**.

Question? "How do you track a satellite without a PC?"

Answer: In the *old days* you had the choice between an *OSCARLOCATOR*, (a kind of graphic overlay system) and a list of Keplerian elements, a trigonometry kit and a *lot* of patience. There *were* other systems but all were fairly tedious.

Today one can use a Kenwood TH-7 handheld or TH-7000 mobile rig. Both are designed for APRS operation and show the position, date, time, azimuth and elevation for any satellite which has its Keplerian elements entered into a program called **APRStk.EXE** by Bob Bruninga, WB4APR. **A COMPUTER IS NOT REQUIRED** to receive tracking data. All that is required is that at least 1 (one) station with a PC within TX/RX range of you is running APRStk.EXE. You will then receive the UI packets and the tracking information will appear on the screen of your rig. Now you can operate (for instance) AO-27 and UO-14 portable or mobile without having to carry a PC or printouts around with you.

Naturally, here in Europe we're a bit slow *launching* this new system. A look at the world map supplied with the program shows the stations using this program are predominantly North American. I hope the idea catches on in other countries so we can have a truly world-wide communications system on VHF/UHF.

Such a system was unheard of just a few years ago but thanks to Bob Bruninga's, vision it's here now. As previously mentioned, *a picture is worth a thousand words* so the **APRN** (see above) could be literally just around the corner. Let's see some cooperation between the smart chappies to produce some sort of satellite system/protocol for *face to face* SSTV.

And the **Kenwood VC-1H** is only the start. Only a short while ago some members were complaining that AMSAT was *going stale*. A few moments juggling the grey cells ought

to ensure that one realizes the potential has never been so good. So may I respectfully suggest you all get off your collective bums! Stop being lethargic and **DO** something about it.

Antenna

I previously mentioned the AO-27 and/or UO-14 antenna I made from 2 x Vargarda beams. The only problem with this was it was rather like having a porcupine in the car when moving from one QTH to another. What was needed was the same kind of antenna (almost) that would *break down* even further. After considering the problem I came up with the idea of using telescopic whips with snap-on BNC connectors for the 2m elements and instead of using 1/4 wave elements centered on the 70cm boom I'd use 1/2 wave elements as phased verticals. **Why 1/2 wavelength? No groundplane needed of course!** The only thing would be matching and phasing the elements.

Commercial 1/2 wave whips are inductively matched to 50 ohm so the phasing lines wouldn't present any problem. The main matching problem would be the home brew high pass/low pass filters of the diplexer since the antenna is designed for transmitting on 2m and receiving on 70cm. The starting point was mounting the 2m antenna on the 70cm boom (at right angles to the 70cm elements). The boom is one-inch square aluminum. I made 3 x "L" clamps and attached female chassis BNC's to the clamps (because they were in the junkbox!). This would ensure the elements could be adjusted for both length and spacing. 3 x BNC barrel connectors were inserted into the BNC's and 3 x AEA "HOTROD" 1/2 wave whips were snapped onto the BNC barrels. The spacing from the reflector to the driven element whip was 43 cm and the spacing between the driven element and director was 33cm.

Initially the reflector and driven element whips were fully extended while the director was pushed in to be approximately 7 cm shorter than the other two. The whips were mounted vertically on top of the 70cm ant boom and the 70cm elements were horizontal. Both antennas had short lengths of RG-58 leading to the diplexer. The idea was to see where we stood impedance-wise before calculating the phasing lines etc. I connected a UHF wattmeter to do some initial testing.

I Was Gobsmacked!

The antenna showed full forward power with absolutely no SWR. (I couldn't believe this!) I performed several tests and confirmed the results. I had a parasitic beam (*Don't you mean paralytic! beam?.....GM1SXX*). Based on the theory "when it works DON'T repair it. I decided to forget the phased array and just operate the antenna "as is." Theoretical gain is about 6 dB or thereabouts. Perfect for AO-27 or UO-14 if you're running five watts.

Important Notes

- Copy on 70cm with vertical polarization was good. With horizontal polarization it didn't even open the squelch! **YOU HAVE BEEN WARNED!**
- If you're running 50 watts or so (like some people) please disconnect the antenna! You don't need it!

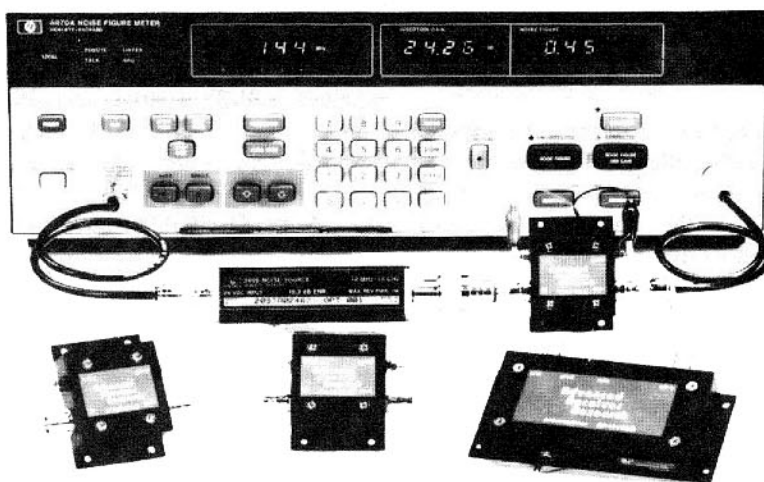
- The standard of operating has fallen dramatically over the last 30 years. They tell me Sainsbury's are giving away Ham licenses with every 10lb of spuds purchased.

Thought for the Day for UO-14: When everybody is calling CQ.....No-one can answer! (Think about it.)

Legs

Just read the AMSAT News Service for the 7th of April and learned that the forthcoming Shuttle mission is delayed *due to the Commander's left leg isn't fully recovered*. Any idea what a Shuttle mission costs? **PULL THE OTHER ONE.....leg, that is. Makes you wonder if that bulletin ought to have been sent out on the 1st of April. 73 y'all de LA2QAA. ■**

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Receive Only	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
P28VD	28-30	< 1.1	15	0	DGFET	\$29.95
P50VD	50-54	< 1.3	15	0	DGFET	\$29.95
P50VDG	50-54	< 0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	< 1.5	15	0	DGFET	\$29.95
P144VDA	144-148	< 1.0	15	0	DGFET	\$37.95
P144VDG	144-148	< 0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	< 1.8	15	0	DGFET	\$29.95
P220VDA	220-225	< 1.2	15	0	DGFET	\$37.95
P220VDG	220-225	< 0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	< 1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	< 1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	< 0.5	16	+12	GaAsFET	\$79.95
Inline (rf switched)						
SP28VD	28-30	< 1.2	15	0	DGFET	\$59.95
SP50VD	50-54	< 1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	< 0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	< 1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	< 1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	< 0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	< 1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	< 1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	< 0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	< 1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	< 1.2	17	-20	Bipolar	\$79.95
SP432VDG	420-450	< 0.55	16	+12	GaAsFET	\$109.95

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**Advanced
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Wideband & Low-Noise Microwave VCO

Matjav Vidmar, S53MV

Oscillators for Spectrum Analyzers

An important piece of radio-frequency or microwave test equipment is certainly the RF spectrum analyzer.

Spectrum analyzers can roughly be divided into groups: professional and low-cost. Although there are many differences between these two groups of instruments, the most important difference is in the type of (sweep) oscillator used for the first frequency conversion.

Professional spectrum analyzers use YIG (Yttrium-Iron Garnet) oscillators. YIG resonators can be tuned over wide frequency ranges (more than an octave in the microwave frequency range) with an external DC magnetic field. YIG resonators also have a high Q allowing a low phase noise when used in an oscillator. Finally, the tuning characteristic of a YIG oscillator is linear, since the frequency is directly proportional to the applied DC magnetic field.

Low-cost spectrum analyzers use varactor (varicap) tuned oscillators. The Q of varactor diodes is rather low and is inversely proportional to the operating frequency. Silicon varactors usually have a Q less than 30 at 1 GHz. GaAs varactors are somewhat better, but they are not easily available and are much more expensive. The frequency coverage of low-cost spectrum analyzers is

therefore limited below 1GHz and the phase-noise performance is usually 20-30dB worse than that of YIG oscillators.

A spectrum analyzer can also be built by a skilled radio amateur. While most circuits of professional spectrum analyzers can be reproduced in amateur conditions, the major problem is building a wideband, low-noise VCO for the first (swept) conversion. YIG oscillators probably can not be built in amateur conditions. The price of a new commercially available YIG oscillator is comparable to the price of a surplus professional spectrum analyzer.

A varactor-tuned VCO covering the frequency band 2-4 GHz will be presented in this article. Such a VCO allows the design of a spectrum analyzer with the first IF in the 2 GHz range, similar to professional instruments. The phase noise of the described VCO is reasonably low, within 20dB of a free-running YIG oscillator. Finally, the VCO design is fully reproducible using standard SMD parts installed on a conventional FR4 (0.8mm thick) printed-circuit board.

Some Oscillator Fundamentals

The design of an amateur RF spectrum analyzer therefore depends strictly on the type of VCO that is available for the first conversion. In order to explain the design of

a wideband varactor-tuned VCO, some oscillator basics have to be discussed first. Any oscillator must contain an active device (gain) and a feedback network, as shown on Figure 1. There are two conditions for oscillation: enough gain (including feedback loss) and correct phase of the feedback.

The frequency of oscillation is determined by both conditions as shown in Figure 2. However, close to the actual oscillation frequency, the gain curve has a broad and flat peak. Therefore, the exact frequency, the stability of the oscillator and the phase noise are all determined by the phase response. The steeper the phase slope, the better the stability of the oscillator and the lower the phase noise.

Low-frequency oscillators are usually designed for operation at a total phase shift of 2π radians. π radians are usually provided by the active device (transistor) itself, while the remaining π radians are provided by the feedback network. A steep phase slope is obtained by a high-Q LC tuned circuit or quartz-crystal resonator.

At frequencies above 1 GHz the phase shift of all known active devices is much larger than π radians due to chip and package parasitics. If an oscillator is designed for a total phase shift of 2π radians, then only a small fraction is left to the feedback network. The phase slope of the latter is certainly not very steep resulting in poor stability and high phase noise.

In the case of a variable-frequency oscillator, the frequency coverage is rather restricted since the influence of the feedback network is small compared to the active device itself. Conventional oscillator designs (with a LC circuit or transmission-line equivalent coupled to a negative-resistance active device) will only provide a restricted frequency coverage and poor stability. Most microwave oscillators are designed in this way, since a negative resistance can easily be obtained from most microwave transistors when considering chip and package parasitics.

Replacing a negative-resistance device with a true two-port, unidirectional amplifier provides the oscillator designer with some more degrees of freedom. In particular, the feedback network can be tailored for the

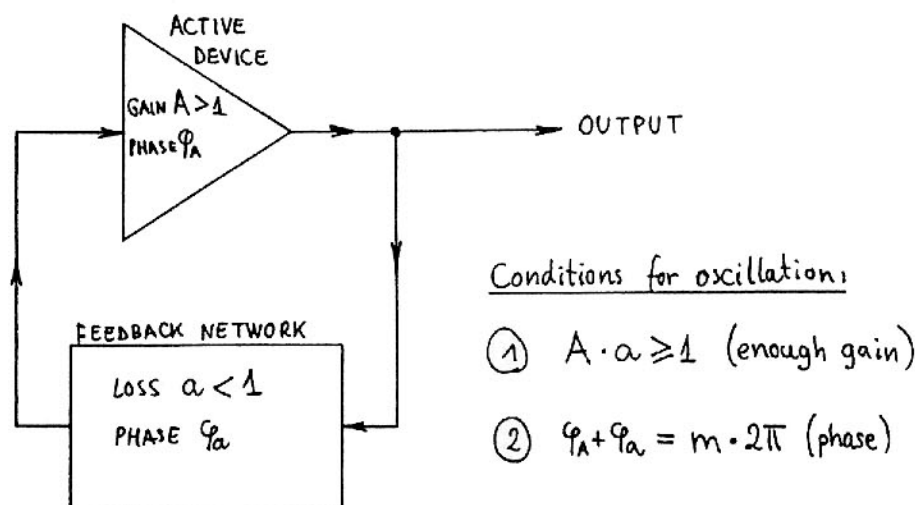


Figure 1 - Oscillator block diagram.

desired amplitude and phase response. The feedback network should both match the impedances and compensate the phase shift of the active device as well as introduce its own, frequency-dependent amplitude and phase response.

A successful wideband microwave VCO design is shown in Figure 3, covering more than an octave with conventional silicon varactors. Although I developed this circuit for my first spectrum analyzer built in 1985, I published the circuit diagram one year later as part of a satellite-TV receiver indoor unit [1], [2]. Many other amateurs used this circuit in their own spectrum analyzers and other RF test equipment, but only few acknowledge the original source [3].

The major drawback of the VCO design from Figure 3 is that its operation is still based on lumped components: capacitors (varactors) and inductors. Its upper frequency limit is therefore defined by the parasitic inductance of available (packaged!) varactors to about 2-2.5 GHz. The phase noise can be reduced by a carefully-designed bias regulator, to stabilize the current through the bipolar transistor, so that the impedances and phase shifts do not change.

Interdigital-Filter Microstrip Oscillator

Active-device phase shifts become much larger at higher frequencies. For example, the phase shift inside a helium-neon laser tube may reach one million radians, although its theory of operation is the same as for other electrical oscillators. The total amplifier plus feedback phase shift still has to be an integer multiple "m" of 2π radians, however "m" is not restricted to unity and may become very large at lightwave frequencies.

Lumped-component oscillator designs become useless at microwave frequencies, since all available components behave as sections of transmission lines. On the other hand, additional phase shifts can be readily implemented as sections of transmission lines. The total phase shift of a microwave oscillator may be an integer multiple "m" of 2π radians. "m" may be larger than unity, but still relatively small at microwave frequencies.

Most microwave circuits are built in microstrip technology, since the latter is compatible with inexpensive manufacturing techniques like printed-circuit boards and surface-mount components. An example of a

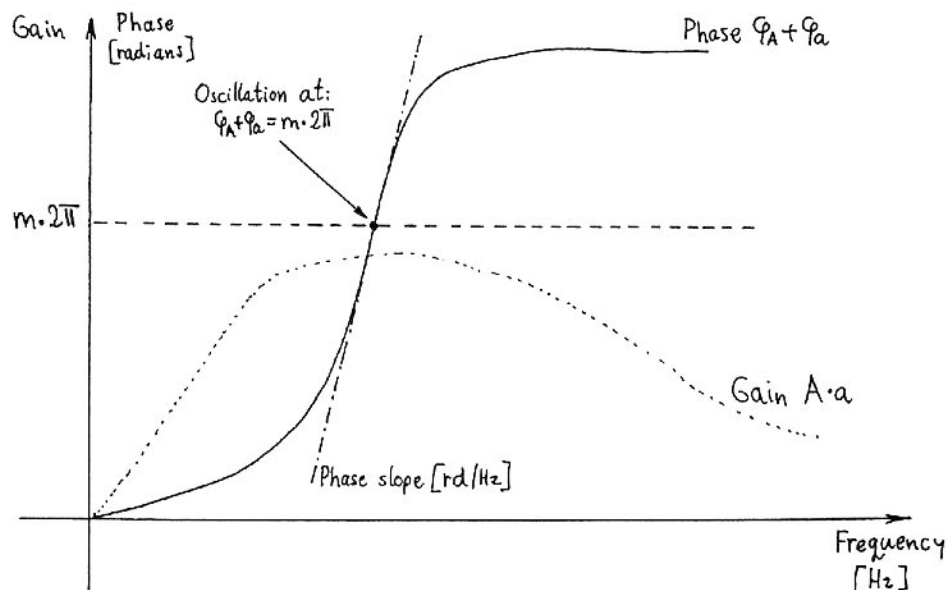


Figure 2 - Frequency of oscillation.

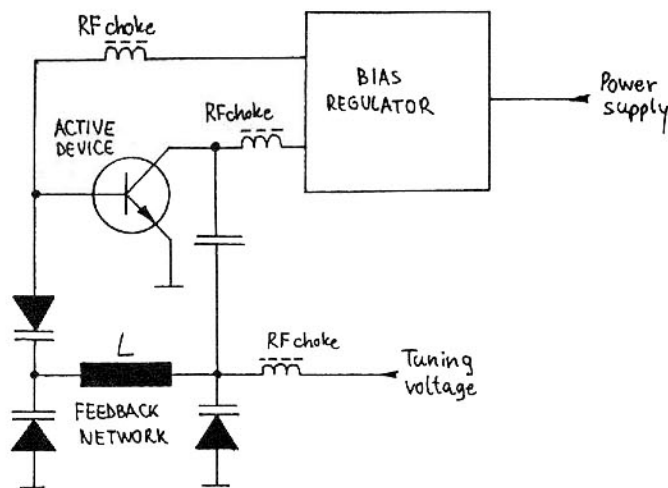


Figure 3 - Wideband microwave VCO.

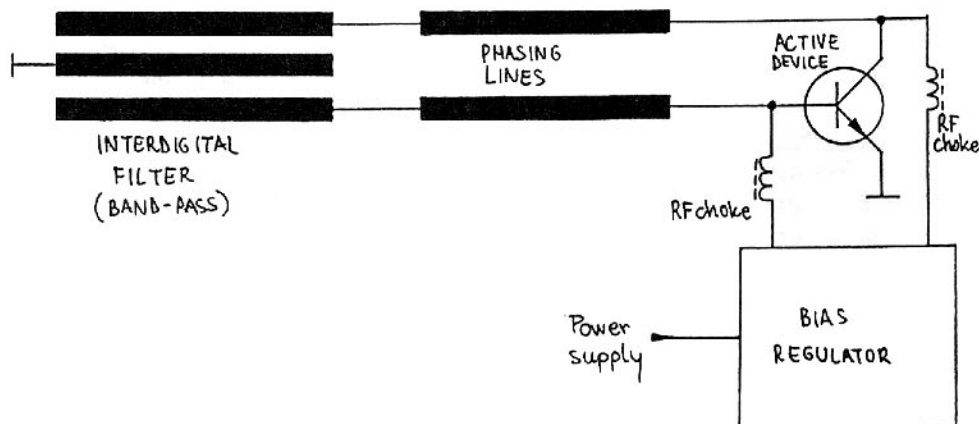


Figure 4 - Interdigital-filter oscillator.

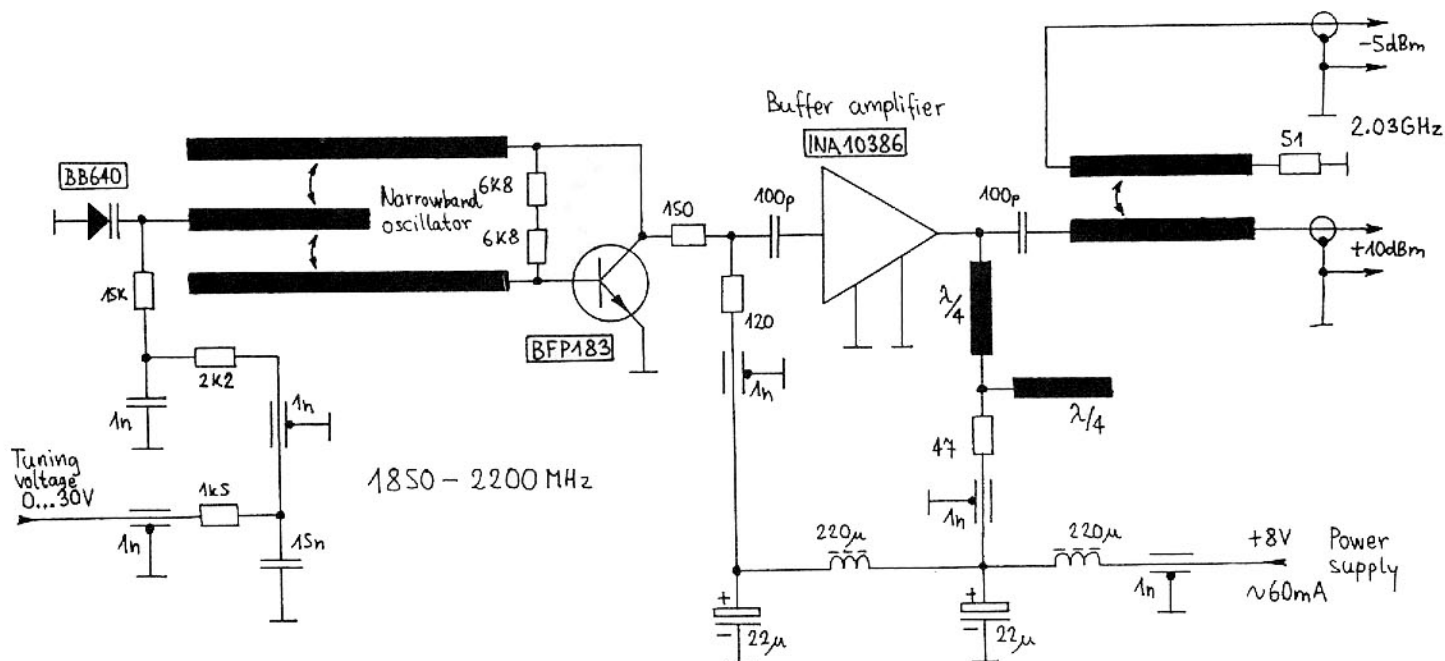


Figure 5 - Narrowband low-noise VCO.

microstrip oscillator is shown as Figure 4. An interdigital band-pass filter is used as part of the feedback network. In order to bring the total phase shift to an integer multiple of 2π radians, additional delay lines may be required to obtain the correct feedback phase.

Although the described oscillator may look complicated, it includes some advantages when compared to conventional low-frequency designs. Although the Q of microstrip resonators is not very high (in the range of 50-100), the phase slope may be made high thanks to the large total phase shift (increasing the multiple of 2π radians). On the other hand, oscillation at unwanted multiples of 2π radians can be suppressed by tailoring the amplitude response of the feedback network.

A fixed-frequency oscillator can be modified into a VCO by tuning the band-pass filter. For narrowband operation it is sufficient to tune one of the quarter-wavelength fingers of the interdigital filter. A varactor is therefore inserted in the central finger, since the latter has the highest loaded Q and provides the highest tuning sensitivity.

The varactor should be inserted either in parallel with a voltage maximum or in series in a current maximum along the length of a resonator. Since the capacitance of most varactors is quite high for microwave

frequencies, varactors are usually installed in series in current maxima. In the case of a quarter-wavelength resonator, the "cold end" of the latter is grounded through a varactor diode.

The circuit diagram of a narrowband low-noise VCO is shown in Figure 5. The circuit diagram includes an output buffer (INA10386) to isolate the oscillator from load variations. Some supply voltage and tuning voltage filtering is included for the same purpose, as well as an output coupler for an auxiliary output.

The tuning range of an interdigital oscillator with one single varactor is limited to about 10-20% of the central frequency. The frequency range of the oscillator on Figure 5 is about 1850-2200 MHz. Outside this frequency range oscillation is not possible, since the gain maximum does not match the correct phase of the feedback.

A narrowband low-noise VCO has many applications in frequency synthesizers. The phase noise is sufficient for both analog (SSB) communications [4], [5] as well as digital (coherent PSK) communications [8], [9], [10]. Used in a fast PLL it even allows the correct demodulation of complex radio navigation signals [6], [7].

The tuning range can be increased by increasing the coupling in the interdigital filter. This decreases the loaded Q of the resonators, degrading the phase-noise performance. Further, such an oscillator may also oscillate on higher-order resonances of the interdigital filter. This effect can be observed as *kinks* in the voltage/frequency curve, which is no longer monotonic.

Wideband Low-Noise Microstrip VCO

To obtain a true wideband microstrip VCO, all fingers of the interdigital filter have to be tuned. For example, inserting one BB833 varactor in each of the three fingers of the interdigital band-pass allows a tuning range up to 50 percent of the central frequency. For example, a VCO with three BB833 and a BFP183 ($f_t = 8$ GHz) as the active device operates reliably in the frequency range 2.0-3.2 GHz. Using a better transistor like the BFP420 ($f_t = 25$ GHz) allows to shift the frequency range up to 2.6-3.8 GHz.

A VCO with contiguous frequency coverage of 1200 MHz may look as the upper limit for BB833 varactors (minimum capacitance 0.75 pF, series resistance 1.8 ohm). Once again, even better results can only be obtained by changing our way of thinking. Varactors are usually considered as discrete lumped components while our oscillator is built with

resistors). All these losses must be recovered with the gain of the active device. A high f_t transistor like the BFP420 is required for such an oscillator. Maybe the described oscillator could also be modified for other active devices, like GaAs FETs, HEMTs, HBTs or MMICs.

Just like its narrowband counterpart the circuit in Figure 6 includes an output buffer (another BFP420 and an ATF35176 HEMT) to isolate the oscillator from load variations. The buffer frequency response is selected to partially compensate the output level variation across the octave frequency band. Some supply voltage and tuning voltage filtering is also included. An output coupler provides an auxiliary output, for example to feed a PLL prescaler, a frequency counter or a tracking generator for the spectrum analyzer.

The measured tuning characteristics of three wideband VCOs are shown in Figures 7 and 8. The main difference between VCO#1 and VCO#2 is in the printed-circuit board. VCO#2 uses lower impedance lines and the coupling between resonators is weaker. There are also differences in the BB833 varactors used: VCO#1 has rather old BB833s providing a coverage of only 1.8GHz while

VCO#2 has new BB833s providing a coverage of 2 GHz. Finally, VCO#3 is built on the same microstrip board as VCO#1, but uses the new BB857 varactors resulting in a frequency coverage of 2.2 GHz.

The tuning curves of all three VCOs are monotonic without kinks or jumps. The curves are quite non-linear as shown in Figure 8. All three curves are the steepest at band center around 3 GHz (or at tuning voltages in the 5-10V range). Both below and above the tuning slope decreases, falling at the upper end (30V) down to less than 1/10 of the maximum slope. The frequency coverage of all three VCOs can be extended on the lower end by about 50 MHz by applying a small negative voltage (about -0.7V) to the varactors.

The phase noise was accurately measured for VCO#1 and VCO#2 and the averaged results are shown in Figure 9. The phase noise is about 5dB worse at band center than at band edges. The phase noise peak coincides with the maximum tuning slope, indicating that at least part of this noise is caused by the varactors used and in particular by the 22kohm bias resistors.



TUNING VOLTAGE [V]	f VCO #1 BB833+PCB#1 [MHz]	f VCO #2 BB833+PCB#2 [MHz]	f VCO #3 BB857+PCB#1 [MHz]
0	2013	2041	2388
1	2103	2140	2507
2	2192	2241	2618
3	2289	2356	2732
4	2411	2506	2848
5	2539	2692	2982
6	2660	2895	3124
7	2798	3047	3256
8	2950	3160	3375
9	3076	3250	3485
10	3190	3336	3588
11	3275	3412	3683
12	3349	3478	3772
13	3415	3538	3846
14	3474	3594	3929
15	3526	3645	4011
16	3575	3694	4085
17	3619	3737	4155
18	3657	3778	4219
19	3691	3816	4274
20	3720	3853	4325
21	3742	3887	4367
22	3760	3919	4407
23	3775	3948	4443
24	3786	3973	4476
25	3795	3994	4505
26	3805	4011	4530
27	3812	4024	4551
28	3818	4035	4568
29	3824	4043	4582
30	3829	4050	4593

Figure 7 - VCO tuning characteristics table.

In order to decrease the phase noise, the 22k ohm bias resistors should be replaced by suitable RF chokes. Unfortunately, suitable chokes are not easy to find. The resistor values can not be decreased much without introducing additional insertion loss in the feedback network. Finally, a more sophisticated bias regulator for the BFP420 oscillator transistor should also bring some improvement in the phase noise.

Practical Microstrip VCO Construction

Both the narrowband and the wideband VCOs are built as microstrip circuits on conventional, double-sided, 0.8mm thick glassfiber-epoxy FR4 laminate. The upper sides are shown in Figure 10 while the bottom sides are not etched to act as groundplanes. Although the FR4 is quite lossy at microwave frequencies, the losses in the BB833 or BB857 varactors are even higher, so using inexpensive and easy-to-handle FR4 laminate is not a drawback.

The dielectric constant and losses of 0.8mm thick FR4 laminate were found quite similar even for materials obtained from different suppliers. One should only be careful about the thickness, since the same microstrip VCO circuit may not oscillate at all on 0.7mm thick laminate (too weak coupling between microstrip lines) or cover a restricted frequency band on 0.9mm thick laminate (coupling too strong). An additional problem is the large temperature coefficient of the FR4 laminate, shifting the frequency of the VCO downwards with increasing temperature.

All three printed-circuit boards have the same dimensions: 20mm (width) x 80mm (length). The whole surface of the groundplane may be tinned, while one should try to avoid tin-plating the microstrip lines on the upper surface except for the areas where SMD components are installed. The boards do not have plated-through holes. All ground connections are made through 2.5mm diameter holes. The latter are first covered on the ground-plane side with thin (0.1mm) tinned copper foil and then filled with solder. The advantages of this grounding method are a low inductance to ground and easy removal of installed components, without damaging the board nor the component to be removed.

Supply and tuning voltages go through several feed-through capacitors. Some feed-through capacitors (3 or 4) are installed in the printed-circuit board itself in 3.2mm diameter holes drilled at the marked

positions. Wire-leaded 1/8W resistors are used to connect the feed-through capacitors to the microstrip circuit. Electrolytic capacitors, 220uH chokes and other filtering components are installed on the groundplane side and are supported directly by the feed-through capacitors.

Finally, two feed-through capacitors are also installed in the 0.5mm thick brass walls of the box housing the VCO. The box should be 30mm high, extending 20mm above the board surface and some 9mm below the board bottom. If the printed-circuit board is well soldered on all four sides to the brass frame, then no additional shielding is required on the bottom side with supply filtering components. On the upper side a shielding cover is required and some microwave absorber is recommended.

In the frequency range of interest only teflon-insulated coax cables should be used. Both flexible and semirigid teflon cables can be used. The cable end should be first prepared by tinning both the inner conductor and the shield. Then the inner conductor should reach the microstrip board through a 3.2mm diameter hole in the brass walls, while the shield is soldered all around the perimeter of the hole.

The microstrip boards should be checked before installation in the shielding enclosure. Both narrowband and wideband VCOs should be checked for frequency coverage and output power level. In particular the PCB#2 for the wideband VCO may require some trimming of the central resonator length if the power drops or the oscillator stops at low tuning voltages. The output power of the buffer amplifier should not drop below +10dBm in any of the oscillators shown.

Applications of Microwave Varactor-Tuned VCOs

Microwave VCOs have many applications. Narrowband VCOs are suitable for many frequency-synthesizer projects. Wideband VCOs are mainly intended for instrumentation, like CW and sweep generators, spectrum analyzers and corresponding tracking generators. In the following paragraph a simple spectrum analyzer using both described VCOs will be presented, although for space reasons the description will be limited to the block diagram as shown in Figure 11.

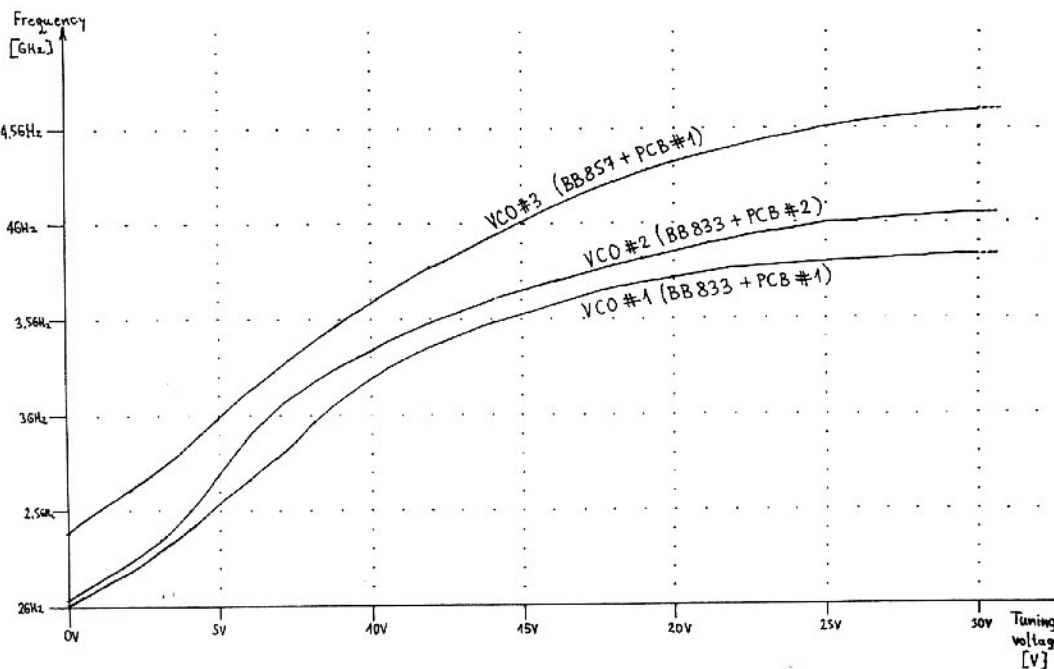


Figure 8. VCO tuning characteristics diagram.

The design of a spectrum analyzer is based mainly on the available wideband VCO. Considering the frequency coverage of the described VCOs and the amateur microwave allocations (1.3 GHz and 2.3 GHz) and satellite frequency bands (GPS at 1.575 GHz, weather satellites at 1.7 GHz) it makes sense to select the first IF at 2.1 GHz. This is far enough from 2.3 GHz and allows a simple input lowpass filter for the band from 0 to 1750 MHz.

On the other hand, the last IF is set down to 10 MHz (10.7 MHz) due to the design restrictions of LC and xtal filters and the

logarithmic detector. To simplify image and spurious filtering, the first IF at 2.1GHz is first converted to a second IF of 70MHz and the latter is afterwards converted to the final third IF of 10MHz.

The IF filters offer six different bandwidths: 4 MHz, 700 kHz, 150 kHz, 50 kHz, 20 kHz and 10 kHz. The 4 MHz bandwidth is required for full-band sweeps, considering the limited resolution of the CRT display. On the other side, the resolution of the spectrum analyzer is limited to 10 kHz bandwidth and 50 kHz/div display. Narrower IF filters would require additional stabilization circuits for all

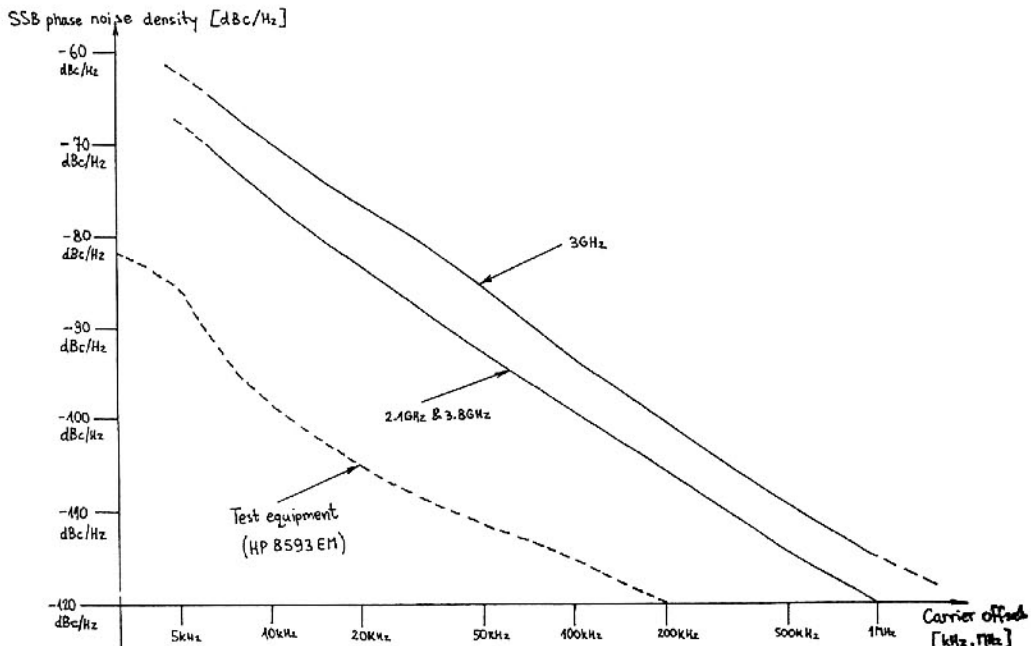


Figure 9 - VCO phase noise.

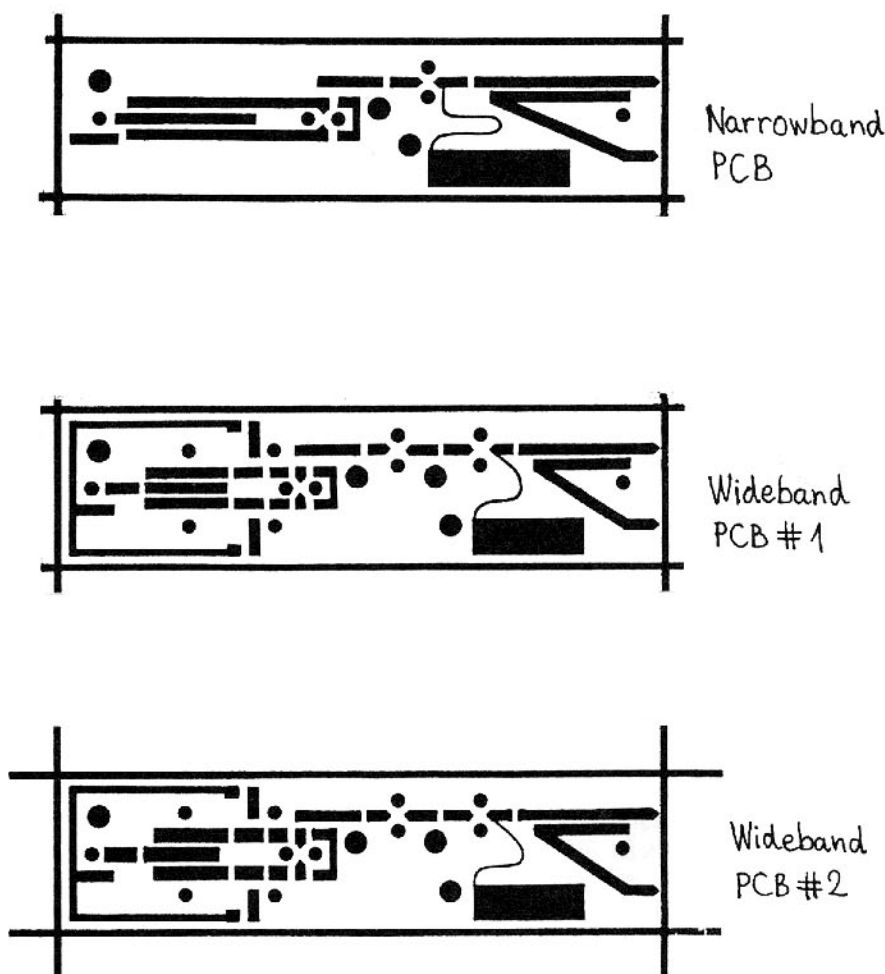


Figure 10 - Printed-circuit boards (SCALE 1:1).

oscillators. Since narrow IF filters also require very slow scanning, they are rarely used and were omitted in this project.

The logarithmic detector is built with discrete components, since available integrated circuits will not handle a dynamic range of over 90 dB (achieved already with the 150 kHz IF filter) and many different IF bandwidths at the same time. The following video amplifier provides a 20dB/V output to drive the vertical deflection of the CRT display as well as an AF (earphone) output. Of course the latter is only useful at zero span.

On the other hand, the horizontal deflection signal (5Vpp) is provided by the built-in sawtooth oscillator. The latter may sweep the frequency of the first local oscillator (wideband VCO) or the frequency of the second local oscillator (narrowband VCO for

500kHz/div or less). Due to the nonlinear voltage/frequency response, the wideband VCO requires a rather complex linearization circuit.

The spectrum analyzer is designed to use a standard XY oscilloscope display. If an external X deflection is not available, the spectrum-analyzer electronics also provides trigger pulses for the time base of the oscilloscope display. Z-axis or display blanking has two functions in a spectrum analyzer: retrace blanking and out-of-band blanking. If a Z-axis (intensity) input is not available on the CRT display, then the blanking output (open collector) may be wired in parallel with the Y output to deflect the trace outside of the visible screen when the blanking is active.

[1] Matjav Vidmar, "Empfangsanlage fuer TV-Satelliten, Teil 2: Die Innenenheit," pages 194-215/4-86, UKW-Berichte/VHF-Communications, Baiersdorf.

[2] Matjav Vidmar, 'TV Satellite Receive System, Part 1: Low-Noise 11 GHz Down-Converter, Part 2: Indoor Unit', pages 1-19 & 20-40, UKW-Berichte/VHF-Communications, Reprint for Siemens AG, Munich, Germany

[3] Dr. Ing. Jochen Jirmann, "Breitband-VCO in Microstrip Technik," pages 3-11/1-92, UKW-Berichte/VHF-Communications, Baiersdorf.

[4] Matjav Vidmar, "A Satellite Receiving Front-End for 2400 MHz," pages 195-217/Scriptum der Vortraege, 39. Weinheimer UKW Tagung, 17-18 September 1994.

[5] Matjav Vidmar, "Ein Front-End fuer den Satellitenempfang im 13-cm-Band," pages 21-33/2-94, AMSAT-DL Journal, Marburg, Germany.

[6] Matjav Vidmar, "Selbstbau eines Empfangers fuer GPS-und GLONASS-Satelliten, Teil 4," pages 10-24/1-94, UKW-Berichte, Baiersdorf.

[7] Matjav Vidmar, "A DIY Receiver for GPS and GLONASS Satellites, Part-4," pages 35-51/1-95, VHF-Communications, Barby Nr. Rugby.

[8] Matjav Vidmar, "13cm PSK Transceiver for 1.2 Mbits/s Packet Radio, Part-1," pages 130-147/3-96, VHF-Communications, Barby Nr. Rugby.

[9] Matjav Vidmar, "13cm PSK Transceiver for 1.2 Mbit/s Packet Radio," pages 145-175/15th ARRL and TAPR DIGITAL COMMUNICATIONS CONFERENCE, Seattle, Washington, September 20-22, 1996.

[10] Matja~ Vidmar: 'Ein PSK-Transceiver fuer 2.4GHz am Beispiel eines 1.2Mbit/s Daten-Transceivers', pages 179-190/3-97, UKW-Berichte, Baiersdorf. ■

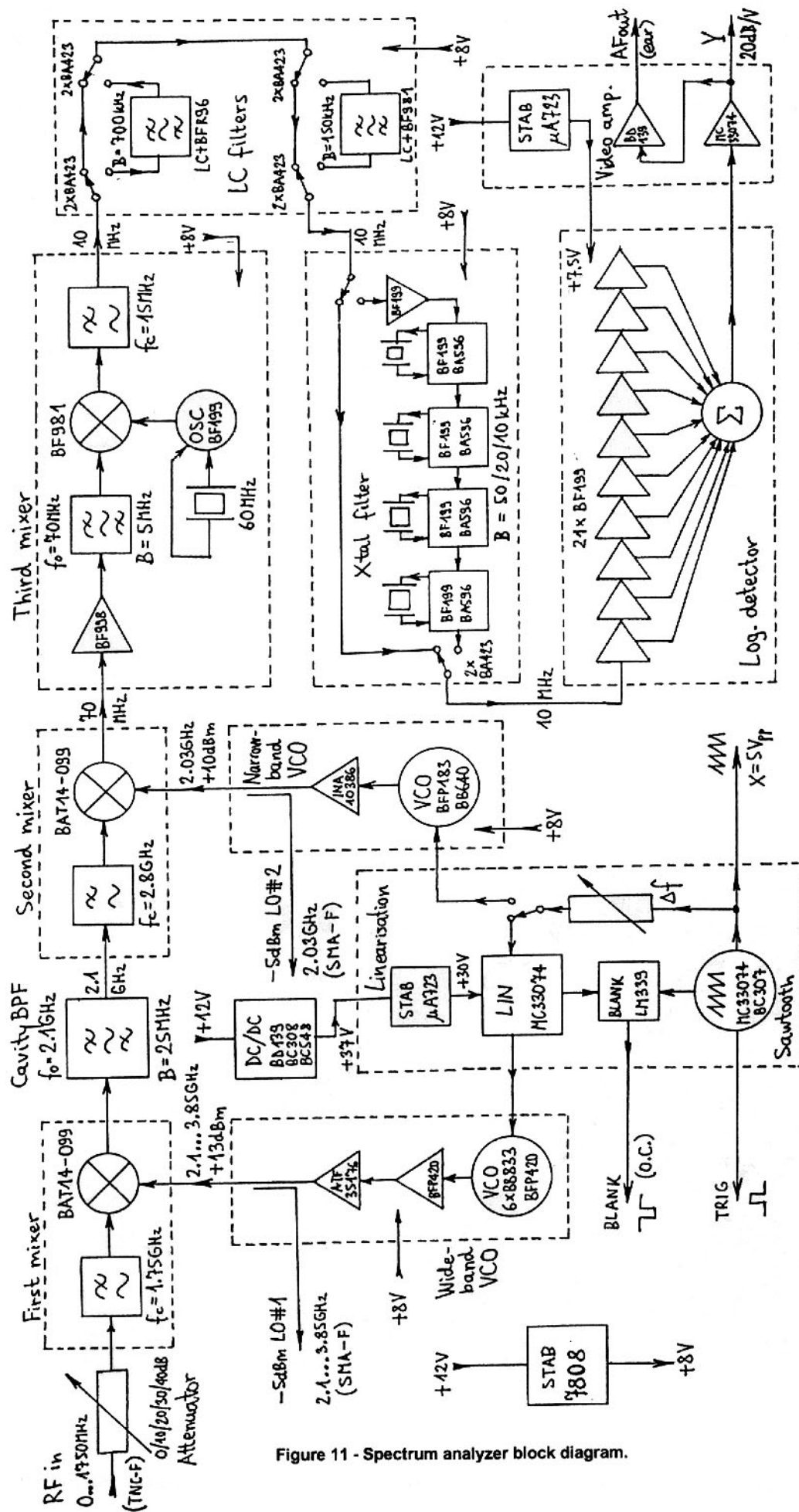


Figure 11 - Spectrum analyzer block diagram.

license on 02 March 2000. Since that time, NASA has translated the Russian Cyrillic to English for the team.

Ariane Flight 506 Delayed

On 12 April 2000, Arianespace announced the next mission of the Ariane 5 heavy-lift launcher, AR-506 (Flight 130), has been postponed due to the unavailability of the Astra 2B satellite, one of the two payloads planned for this mission.

Originally scheduled for launch on 23 May 2000, Flight 130 was slated to have lofted Astra 2B for the Société Européenne de Satellites (SES) and the GE-7 communications satellite for GE Americom.

Arianespace is now planning Flight 130 for July 2000, with the choice of launch vehicle to be based on the availability of customer satellite payloads.

At this time AMSAT-NA and AMSAT-DL are unaware of what effect this delay will have concerning the launch of the Phase 3D satellite.

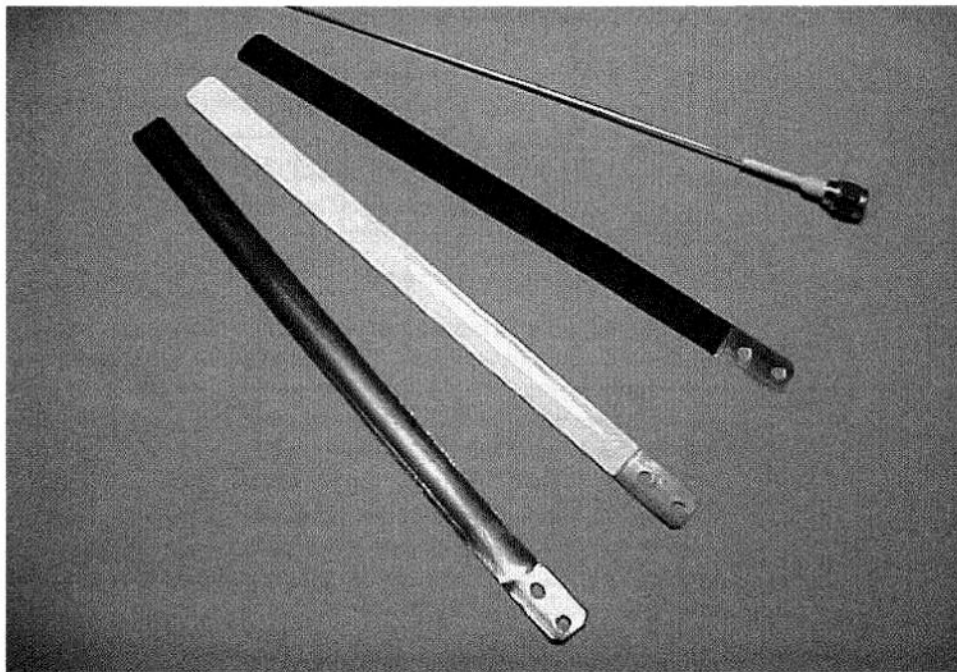
Members of the Amateur Radio on the International Space Station (ARISS) team in the U.S. received word from the Russian team that a Russian station license has been granted for the ISS Ham Radio station. This license is valid for all Amateur Radio hardware that will be located in the Russian Segment. It will support the operation and use of the ham radio station in all of the Russian provided segments of ISS. This includes the FGB (or Zarya) module that is currently on-orbit and the Zvezda Service Module that is planned for launch this summer.

For more information on the ISS assembly sequence, see: <http://spaceflight.nasa.gov/station/assembly/index.html>

During a telephone conversation last week, AMSAT-RU team member Sergej Samburov, RK3DR, informed the U.S. Ham Technical Team that the Russian Federation Communications Oversight Commission has granted a license to operate a *Ham Radio Station of the Highest Public Usage Category* for the ISS Russian Segment. The ARISS US team received a copy of the

Frank Bauer, KA3HDO, ARISS International Administrative Chairman explains that "This specific license enables the on-orbit ISS crews to operate all Amateur Radio modes and bands. It is a critical step in our future operations of ham radio on ISS. We are excited that the Russian team have made significant progress and now have our first license in place." Sergej Samburov explained to the ham team that this license is required before any ham radio equipment can be installed in the Russian Segment. The station license call sign is RZ3DZR. It was issued on 02 March 2000 and is valid until 02 March 2005.

The ARISS International team is working on a long term plan for a single, international ISS station license. This will allow all the international crew members to operate different hardware that will comprise the ham radio station in any part of the ISS without third party restrictions in their country. This was discussed at the ARISS meeting in Surrey, England in July 1998 and at the IARU Satellite Meeting during the 1999 AMSAT-NA symposium in San



70 cm Microsat antenna blades made of tape measure material and a Falconsat-1 piano wire whip. (photo courtesy of Jim White, WD0E)

Diego, California. It is also an agenda topic for the ARISS meeting that was held near Amsterdam later in March. The ARISS team is working with the IARU to develop a long term, international solution. In the meantime, the team is pursuing licenses in each of the member countries. The U.S. team will soon apply for a station license to allow Bill Shepard, KD5GSL, to use the station later this year. In the meantime, the ARISS team is working with the ISS Space Agency partners to prepare the crew and hardware for use later this year.

The Tale of the Tape

Jim White, WD0E, recently provided the following interesting response to an amsat-bb question regarding which satellites currently in operation used carpenter rule tape as antenna:

The four original AMSAT Microsats (AO-16, DO-17, WO-18, and LO-19) all used Stanley brand tape measure material for their antennas. For these Microsats, the Stanley company donated a roll of several hundred feet of unpainted material. To create the Microsat antennas the material was cleaned, primed and painted with space-rated paint (Chemglaze Z306), black on one side and white on the other. The difference in admissivity/absorbitivity (a/e) ratio between the colors provided the major component of the torque which generated spin about the Z axis.

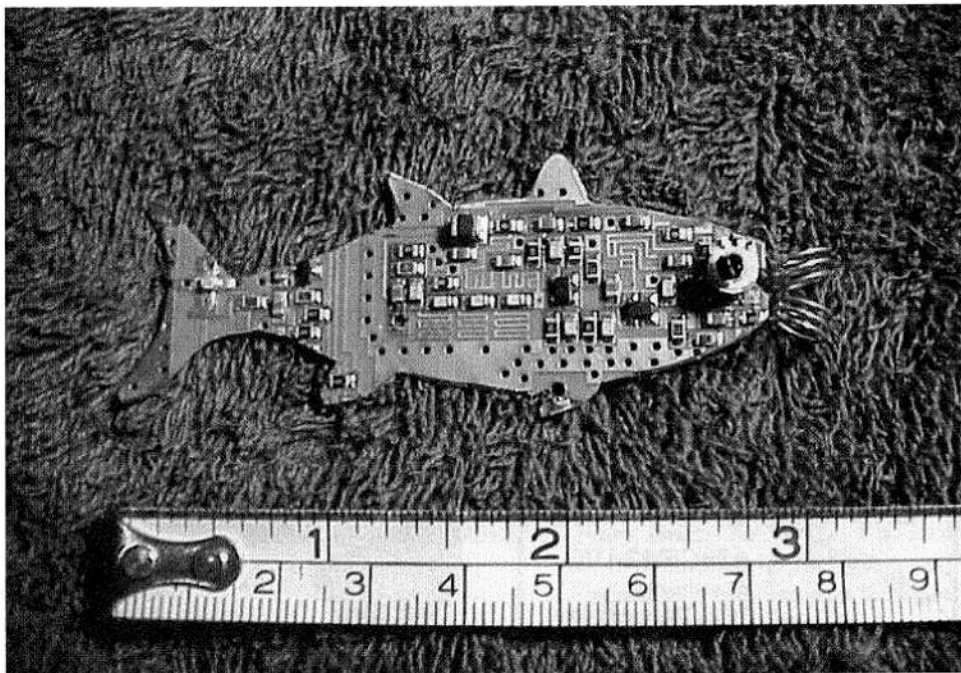
The photo shows (left to right) an untreated Microsat test blade, two flight blades showing the differential painting, and a test Falconsat-1 whip. The Microsat blades are $\frac{3}{4}$ inch wide and 6.26 inches long. The whip is .04 inches in diameter and mounted to an SMA connector.

AMSAT started using tape measure on AO-5. Jan King, W3GEY, remembers using it right off a store bought Stanley tape without disturbing the numbers or paint. And he points out AMSAT picked up the idea from Project OSCAR. The longest he recalls making was a 10 M dipole.

EYESAT (now AO-27) used the same material gold plated then painted black on one side.

Tape measure has been used on UoSats for several years.

UNAMSAT-1 and 2 (MO-30) used it as well, including the 49 MHz dipole. That antenna was folded up and tied with fishing line. A nicrome wire was wrapped around it



Tuney Tuna will be in Portland, Maine this October!

and released the antenna when pulsed with a voltage. If that failed UV would cause the line to deteriorate and release the antennas after a few weeks.

On the January 2000 Minitaur launch, Falconsat-1 used piano wire, ASUSAT-1 and OPAL used tape measure, as did the other payloads. The ASUSat1 blades were purchased at a local tool shop then stripped and coated with Teflon.

One was housed in a tube for launch and needed to slide out with minimal friction at separation. At first glance it looked odd because it was quite green. The local shop that contributed the coating was doing a large batch of green material the day they did the ASUSat1 antennas.

Tape measure has the helpful characteristic of being able to fold or roll up and spring back to its original shape. When mounting a satellite on a launcher it can be bent to fit the available space, held in place with a small bracket or cup, and pop loose nicely at separation.

It does produce some shadowing on solar arrays. If you examine a plot of current from the +Z panel of any of the Microsats you can see the effect of the change in the width of the shadow as the satellite rotates relative to the sun. Because of this problem, more recently some satellites have used piano wire whips. On a tiny satellite the reduction in shadowing translates into a useful increase in power generation. The drawback is that piano wire has somewhat less

bandwidth because it is thinner than tape measure. But that is a minor problem compared to just getting a whip on a box to match somewhere close to the desired frequency, and end up with a pattern something close to what you would like. Piano wire does not have the ability to be radically bent or rolled and spring back to its original shape like tape measure.

As in just about everything related to building a satellite, the choice of antenna material is a set of tradeoffs.

Announcing the Eighth Annual Jewelry Contest

Dave (WB6LLO) and Lenore (KA6UCD) Guimont report that the traditional AMSAT Jewelry Contest will place at the 18th AMSAT Annual Meeting and Space Symposium in Portland, Maine on 27-29 October 2000.

This year's contest is in the form of a brooch that was *carved* out of a gold plated circuit board in the shape of a tuna. The boards were donated by Qualcomm, delivered to the convention floor by Kerry Banke, K6IZW, during last year's convention in San Diego. Proceeds from the donations for the boards were gratefully received by our Phase 3D support group.

The brooch is about 3" long, comes with a safety clasp, and can be pinned on or hung from a suitable chain. We will be visiting an area that has probably the best seafood cuisine anywhere in the world, and we think

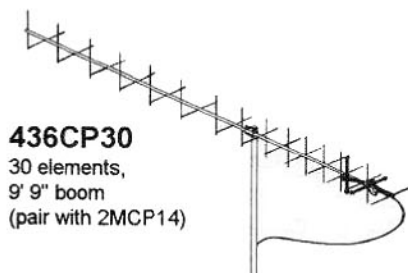
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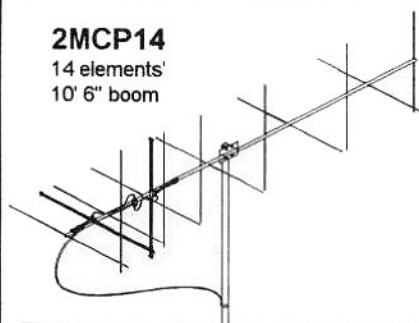
436CP42-U/G

42 elements,
18' 10" tapered boom
(pair with 2MCP22)



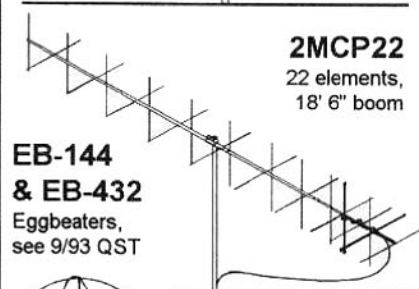
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

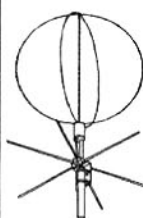
14 elements
10' 6" boom



2MCP22

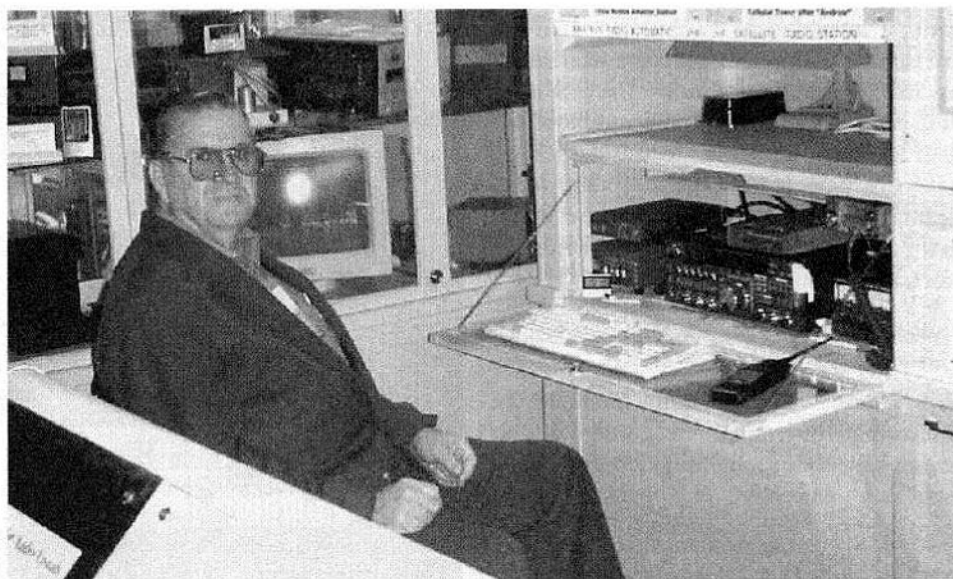
22 elements,
18' 6" boom

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KE4ZXW Celebrates Over Four Years of Operation. Wally Carter, K4OGT, Chief Control Operator welcomes visitors to the KE4ZXW station. Twelve Amateur Radio clubs in the southeast Virginia area have cooperatively designed, constructed, maintained, and manned a world-class Amateur Radio exhibit at the Virginia Air & Space Center in Hampton, Virginia. The focal point of this exhibit is a fully automatic 9600 baud digital satellite station, KE4ZXW. This station operates 24-hours a day in contact with UO-22, KO-23, KO-25, and TMSAT-1. The exhibit has achieved its objective of informing and educating visitors on various Amateur Radio modes and is manned four to six hours a day. Visitors from more than 40 countries and many thousands of students have seen the exhibit in operation. Ken Pierpont, KF4OW says that since start up, no major incidents or breakdowns have occurred; just an occasional operator error!

it is appropriate. The original board components have nothing to do with the solution, but they do provide the scales for *Charlie Tuna*.

Your endeavor, should you choose to take the assignment, will be to determine the resonant frequency of the *parallel tank* circuit formed by the *eye* and the *mouth*. The frequency is in one of the Amateur Satellite bands. The *eye* is a miniature variable capacitor that is set at 7.0 pF. The *mouth* is a coil of #24 plated copper wire. It is 6 turns, .25" in diameter and .25" long. The wire spacing is one wire diameter. The angular separation to form the *mouth* is of some consequence, and should be considered in your calculations. The winner can re-set the capacitor to his frequency preference!!!!

Leaneore will be wearing it at the convention (of course she just HAD to get a new dress!). She calls it the *tuney tuna*. She will present it to the winner at the banquet.

Anyone can enter, and you need not be present to win. If not attending the convention, send your entry by e-mail to ka6ucd@amsat.org or wb6llo@amsat.org. Snail mail to our callbook address, or contact on any amateur frequency will be

OK also. Questions please, to the same place. Please submit your answer as XXX.XXXXXX MHz. There is no way that I could measure it that accurately, but the answer is set that way purposely to eliminate ties.

This narrative [tuna1.txt](http://home.san.rr.com/doguimont/uploads/tuna1.txt) and a graphic [tuna1.jpg](http://home.san.rr.com/doguimont/uploads/tuna1.jpg) at: <http://home.san.rr.com/doguimont/uploads>

And the Winner Is?

Phase 3D Integration Manager, Lou McFadin, W5DID informs us that Chris Karpinsky, KB2HNJ of Otego, NY, has correctly identified the use of the Phase 3D test equipment that appears on page 3 of this issue (and in the last two issues). Chris sent Lou the following e-mail note:

Hello Lou,

Perhaps the bicycle wheel is used to test the sun sensor? That is, when the satellite is deployed, it will be spinning... instead of spinning the satellite to test the sun sensor, you are using a light that is passing through the region of view of the sun sensor?

How's that?

Thanks,

Chris, KB2HJ

Lou informs us that the bicycle wheel is the mount for the simulated sun which is powered through a pair of slip rings. The speed of the wheel represents the satellite rotation rate. Just as Chris surmised. A lamp from an auto headlight had to be used to provide enough light. Even then, it had to pass very close to the sensor.

Well done Chris! As a result of your efforts, a (coveted and soon-to-be-collector's item) AMSAT Phase 3D t-shirt has been placed in the mail to your QTH.

New OSCAR Numbers Assigned

AMSAT-NA President Keith Baker, KB1SF, announced the assignment of several new OSCAR numbers. The new numbers were assigned to the Amateur Radio satellites launched from Vandenberg Air Force Base on January 27, 2000. The launch was aboard an Orbital Sciences Minotaur launch vehicle.

OSCAR numbers are issued by AMSAT-NA at the request of Project OSCAR - which built and launched the first Amateur Radio satellites beginning with OSCAR-1 in 1961.

In order to qualify for an OSCAR designation, certain specified criteria must be met, the most important of which are set forth in a document issued by the International Amateur Radio Union (IARU) titled *Information Paper for Perspective Owners and Operators of Satellites Intended for Operation in the Amateur Satellite Service*. Information on this document is available on the IARU Internet web site and also through a link from the AMSAT-NA web page. The IARU document is based on a similar document published earlier by AMSAT-NA.

Other criteria include the need for a written request by the person or organization responsible for the satellite to be submitted to AMSAT-NA. This request must include information about the satellite (such as frequencies and orbit) as well as a statement that the requirements of the IARU document have been and are being met.

The following OSCAR information is provided relative to the latest number designations:

- JAWSAT (Joint Air Force Weber Satellite): In addition to its own electronic payload, consisted of a structure on which were mounted a number of other spacecraft. These small satellites were ejected from JAWSAT itself. Among these were the several Amateur Radio satellites - which have now received OSCAR numbers.
- ASUSat, built at Arizona State University, is now also known as Arizona State OSCAR-37, or AO-37.
- OPAL, built at Stanford University in California, is designated OPAL OSCAR-38, or OO-38.
- JAWSAT, built at Weber State University in Utah, is designated Weber OSCAR-39, or WO-39.

AMSAT-DC Gathering a Success

by Pat Kilroy, WD8LAQ

AMSAT-DC post-meeting kudos are still flowing in from our Sunday, 2 April 2000 gathering. I'm getting some very nice e-mail responses on how well the local AMSAT-DC gathering at the NASA Goddard Space Flight Center was organized and enjoyed by all. This is wonderful! Instead of posting a blow-by-blow summary of the meeting, let me take this space to say a big thank you to some of those who helped make it happen. And as you can read, this listing provides a good summary of the event!

- John Sortor, KB3XG, and the *Pack Rats*. A very nice presentation and technical session. (John brought expensive test gear to check performance of one's OSCAR station gear free of charge.)
- Gerry Rodski, K3MKZ, and SSB Electronic USA, for the presentation and informative show 'n' tell UHF and above equipment, especially in light of the coming Phase 3D action.
- Geoff Chester of the U.S. Naval Observatory, Washington, DC, for his keynote presentation.
- Eric Rosenberg, W3DQ, for arranging Geoff Chester to be our keynote speaker.
- Joshua Rozovsky, N3YAR, and David Beasley, KF4SVK, two outstanding young gentlemen from Highland Springs High School, Richmond VA who conceived, designed and launched an experimental high-altitude balloon program at

their school and shared the results (a very slick presentation!) of their initial endeavor with us.

- Bob Bruninga, WB4APR, who through a brief presentation and several show 'n' tell items excited us with yet more new and innovative ideas that motivates us to go out and experiment on our own. (Bob also shared his projection unit with other presenters.)
- Dan Schultz, N8FGV, for sharing his latest hardware projects with us, for running errands for the host during the program, and for volunteering as a new AMSAT Area Coordinator.
- Frank Bauer, KA3HDO, who took us to Holland with him via a very interesting presentation on the recent Amateur Radio on the International Space Station (ARISS) developments. Frank also described how AMSAT members can volunteer to join the ranks in developing hardware or to participate in the operations of ARISS activities. (Frank also shared his razor-sharp Power-Point projector with other presenters!)
- Arthur Feller, W4ART, for taking a number of action shots and the group photo at our gathering.
- Tom Clark, W3IWI, for his continuing support and for capturing video and audio on a DV cam.
- Rob Whiteley, W3ROB, for setting up the snack table and acting as impromptu treasurer.
- Jeff Embry, W13T, for staffing the AMSAT table during the gathering, and for volunteering as a new AMSAT Area Coordinator. (Now we need a volunteer from northern Virginia to come forward.)
- Hank Riley, N1LTV, of Massachusetts for his generous shipping and loaning of a SkyQuest Hamradio-sonde mockup for a working high-altitude balloon payload show 'n' tell at our gathering.
- Perry Klein, W3PK, for his continued support and his edible donation at the snack table.
- Hugh O'Donnell, W3FUO, for his efforts to provide an informative and pleasant tour of the WA3NAN Goddard Amateur Radio Club facilities, and his work to improve our talk-in capabilities.



Participants of the AMSAT-DC Gathering, 3 April 2000. (photo by Art Feller, W4ART)

- Martin Davidoff, K2UBC, for his support and allowing individuals to pepper him with questions on his satellite experimenter's book.
- Paul Rinaldo, W4RI, for his support and his announcement on the coming AMRAD attractions.
- Dave Aitcheson, KB3EFS, for his help in acting as Net Control Station for AMSAT-DC talk-in (146.760 MHz).
- Gary Chatters, WA9ZZZ, for his help acting as Net Control Station for AMSAT-DC talk-in (146.835 MHz).
- Charlie Heisler, K3VDB, for conceiving the idea and acting as chairman for the new technical session.
- Allan and Cherise at the GSFC Visitors Center, for the rock solid reservation, the A/V gear, sound system, and all the *little* things that make a meeting of this magnitude go so well.
- Eluid Bonilla, N3QYJ, for his timely announcement of a free all-day microsat seminar at Aero-Astro courtesy Rick Fleeter, K8VK.
- AMSAT Area Coordinator George Caswell, W1ME, and Caroline

Caswell, WA1MER, (hosts of the next AMSAT annual meeting) who receive the AMSAT-DC DX Award for greatest distance traveled, visiting from the beautiful state of Maine. See you in Maine next October!

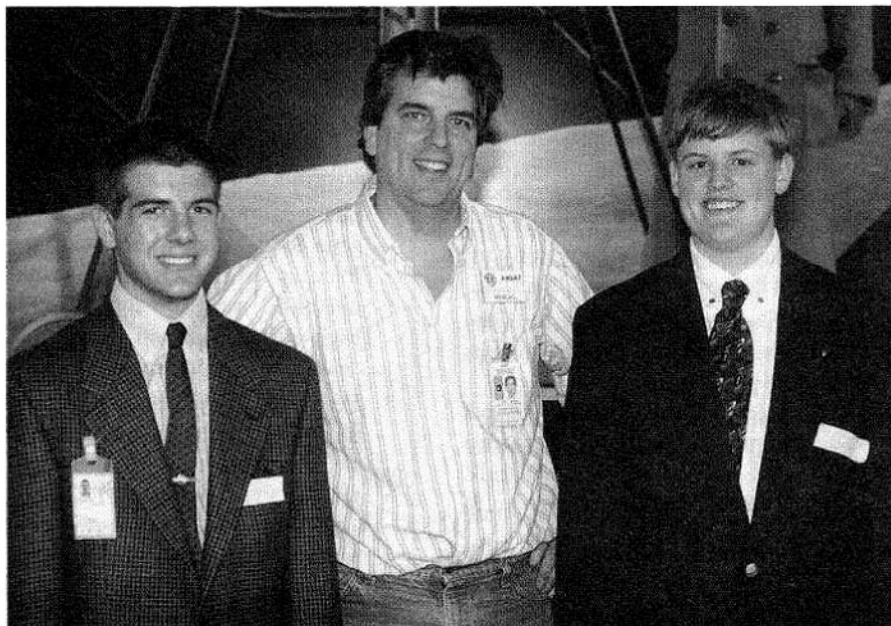
- Jack Colson, W3TMZ, for his cool show 'n' tell table on S-band gear.
- Martha at AMSAT-NA headquarters, What can possibly happen successfully within AMSAT without her?
- Russ Tillman, K5NRK; Dan James, NN0DJ; and Paul Williamson, KB5MU, for their help in publicizing our meeting and space seminar through *The AMSAT Journal*, AMSAT News Service bulletins, and the AMSAT-DC e-mail list, respectively.
- And thank you to the one (Doug?) who stayed late with me cleaning up, putting away tables and rearranging chairs. This prevents us from incurring a cleaning fee, which helps keep meeting costs low — and plainly maintains the good ambassadorship image of AMSAT members.

I am sure I may have missed listing a few folks. For that I apologize. However you should get an feeling that this was truly a *member event*.

We are still looking for someone to offer their notes on the seminar presentations by sending them to the amsat-dc@amsat.org e-mail list. I'd be glad to send a copy of our agenda if needed.

Incidentally, this was the first time since 1992 that we did NOT rely on postage stamps, thus saving on incidental meeting costs. There were over 70 persons who attended this April 2000 meeting, one of the largest to date!

Let's do it again!



Pat Kilroy, WD8LAQ (center) with Joshua Rozovsky, N3YAR and David Beasley, KF4SVK. Joshua and David made a presentation on how they designed and launched a high altitude balloon.

See You at AMSAT Field Day

24-25JUN00

AMSAT Field Day Rules are available via www.amsat.org

**For More Details Contact
Andy MacAllister, W5ACM
(w5acm@amsat.org)**

AMSAT HF/VHF/UHF Nets

Compiled by Andy Reynolds, WD9IYT

HF Nets

Name	Day	Time	Frequency (MHz)	Net Control
East Coast AMSAT Net	Tuesday	2100 Eastern	3.840 (+/- QRM)	Al Tribble, W3STW
Mid-America AMSAT Net	Tuesday	2100 Central	3.840 (+/- QRM)	Keith Pugh, W5IU & Bill Tynan, W3XO
West Coast AMSAT Net	Tuesday	2000 Pacific	3.840 (+/- QRM)	Net is not currently active
AMSAT-UK Net	Sunday	1015 Local	3.780 (+/- QRM)	Richard Limebear, G3RWL
AMSAT International Net	Sunday	1800 UTC	14.282 (+/- QRM)	Net warmup
AMSAT International Net	Sunday	1900 UTC	14.282 (+/- QRM)	Formal Net with Keith Pugh, W5IU; Larry Brown, W7LB; Wray Dudley, W8GQW

VHF/UHF Nets

Name	Day	Time	Frequency (MHz)	Net Control	Notes
Arizona AMSAT Net	Wednesday	2000 Local	146.880 (-)	Larry Brown, W7LB and Jim Weisenberger, AA7KC	This is a mountaintop repeater that provides good coverage of south and central Arizona including both Tucson and Phoenix.
Colorado AMSAT Net	Wednesday	2000 Local	147.225 (+)	Al Ventura, N0SVE & John Gubins, KB0VBZ	
Fort Worth/Dallas AMSAT Net	Wednesday	2100 Local	147.140 (110. PL)	Keith Pugh, W5IU; Doug Howard, KG5OA; Ray Hoad, WA5QGD; Richard Raitt, WA5VKS; Gary Persons, KD5DAY	
Houston AMSAT Net	Wednesday	0100 UTC	145.450 (-)	Andy MacAllister, W5ACM and Bruce Paige, KK5DO	C-band TVRO net on GE-4 transponder 16 upper (H), 5.8 MHz wideband audio located 101W (4 DTV satellite S4, channel 952). Also available via Real Audio at http://www.amsatnet.com/
Los Angeles AMSAT Net	Thursday	1900 Local	145.320 (- & 114.8 PL)	Ronalee Fitch, N6SHI and Stanley Johnson, W6EKK	
Southeast Michigan AMSAT Net	Sunday	2000 Local	145.330, 442.800, 1282.05	James French, KD4DLA	Featured topics on the net include but not limited to: AMSAT News Service Bulletins, ARRL, and NEWSLINE space related Audio News clips NASA Science.com messages, latest Spaceweather.com updates and news NEAR-Shoemaker, Pioneer, Voyager, Space Shuttle, and International Space Station Status reports, MIREX Bulletins, MABEL-1 Balloon updates along with any other balloon launch news, Updates on the status of local Fast-Scan ATV and Audio rebroadcasts of NASA Select, Plus trying to answer any and all questions about AMSAT and Amateur Satellites
Southwest Ohio AMSAT Net	Tuesday	2000 Local	145.110 (-)	Frank McGrath, N8XPC	There are five operators who take turns as NCS, with WB8IFM usually reading bulletins (and acting an alternate NCS) plus handling Q & A sessions.

ICOM IC-821H

"By far the easiest to use satellite radio on the market today. In less than 10 minutes after unpacking the IC-821H, I was on the air at 9600 baud with KO-23."

— Michael Wyrick, N4USI and AO-27 Control Operator



It's 2 RECEIVERS IN 1 COMPACT BOX.

Enjoy full crossband full duplex operation. Use the independent RF attenuators, RIT, IF shift circuits and scan functions. Each band also has its own S-meter, squelch, volume control and independent mode selection.

"SATELLITE FRIENDLY" OPERATION.

Better than just using a high/low setting, the continuous adjustable transmit power feature gives you precise power control. This helps extend the life of amateur radio satellites by running the minimum power necessary. **EXCELLENT SUPPORT FOR CW.** An electronic keyer is built in and optional CW-narrow filters are available separately for the Main and Sub bands. Also get: adjustable keying speed and dot/dash ratio, adjustable delay time for semi break-in operation, and more.

ICOM options required for PC connections:

CT-17 CI-V Level Converter



Other options also required for PC connections:

Third party serial cable, pins 1-8 & 20
Third party software

DUAL DISPLAY
Shows receive (downlink) and transmit (uplink) simultaneously.

SPECIFICATIONS

Transmit: 2 Meter, 440 MHz (70 CM)
Receive: 136-174 MHz, 440-450 MHz (guaranteed 144 - 148 and 440 - 450 MHz only)
Mode: SSB, CW, FM
Power: 2M SSB: 6-35W, continuous
2M CW, FM: 6-45W, continuous
440 MHz SSB: 6-30W, continuous
440 MHz CW, FM: 6-40W, continuous
Power Supply Requirement: ... 13.8 V DC
Memory Channels: 160 Total,
80 Channels Per Band
VHF Antenna Connector: ... SO-239 (50)
UHF Antenna Connector: ... Type-N (50)
Size: 9.5(W) x 3.7(H) x 9.4(D) in.
241(W) x 94(H) x 239(D) mm.
Weight: 11.0 lb
5.0 kg

FEATURES

- **Continuously Adjustable TX Power**
 - More control
 - Extends satellite life by using minimum power
- **Independent Main / Sub Band Rx**
 - Tuning, AF and squelch level, and 4 function control switches per band
 - In Satellite mode, Sub is uplink, Main is downlink
 - IF shift for either Main/Sub band
- **9600 or 1200 BPS Packet Capable**
 - Direct audio modulation
 - Excellent C/N ratio
 - Excellent frequency stability
 - Adjustable ACC modulation signal levels
- **High Frequency Stability**
 - ± 3 ppm standard, ± 0.5 ppm optional
- **100% Duty Cycle**
- **AF Speech Compressor** for increased average talk power
- **Auto Repeater** with one-touch repeater functions
 - Built-In RIT Function
 - Built-In Electronic Keyer
 - RF Attenuator
 - Noise Blanker
 - Tone Encoder (CTCSS)
 - Separate Speaker Jacks
 - 1 jack per band
 - AGC Time Constant Control
 - Auto Repeater Function
 - Rugged ICOM Construction
 - Built-In CI-V Port
 - 2 Optional CW Narrow Filters



NOISE BLANKER
Reduces pulse-type noises

INDEPENDENT CONTROLS
For Main/Sub band

QUIET FAN
Keeps things running cool and quiet

Tx/Rx FREQUENCY TRACKING
Normal / reverse shift

A FEW NOTES FROM THE QST EXPERTS:

"(The IC-821H) is a terrific dual-band multimode transceiver for all applications. Not only is the IC-821H an excellent VHF/UHF weak signal or contest radio, it is the cornerstone of a high performance satellite station (digital or analog). Hams who have the Phase 3D satellite in mind will want to give serious consideration to the IC-821H. It also offers superb FM-voice and 9600-baud packet performance. Combine all of these features with the IC-821H's go-anywhere size and you have a radio that's ideal for almost any application above 144 MHz!"

— QST Magazine, 3/97

For REAL satellite performance, there's only one rig to seriously consider...the IC-821H. Contact your authorized dealer today, or call for a free brochure:

425-450-6088

ICOM
www.icomamerica.com